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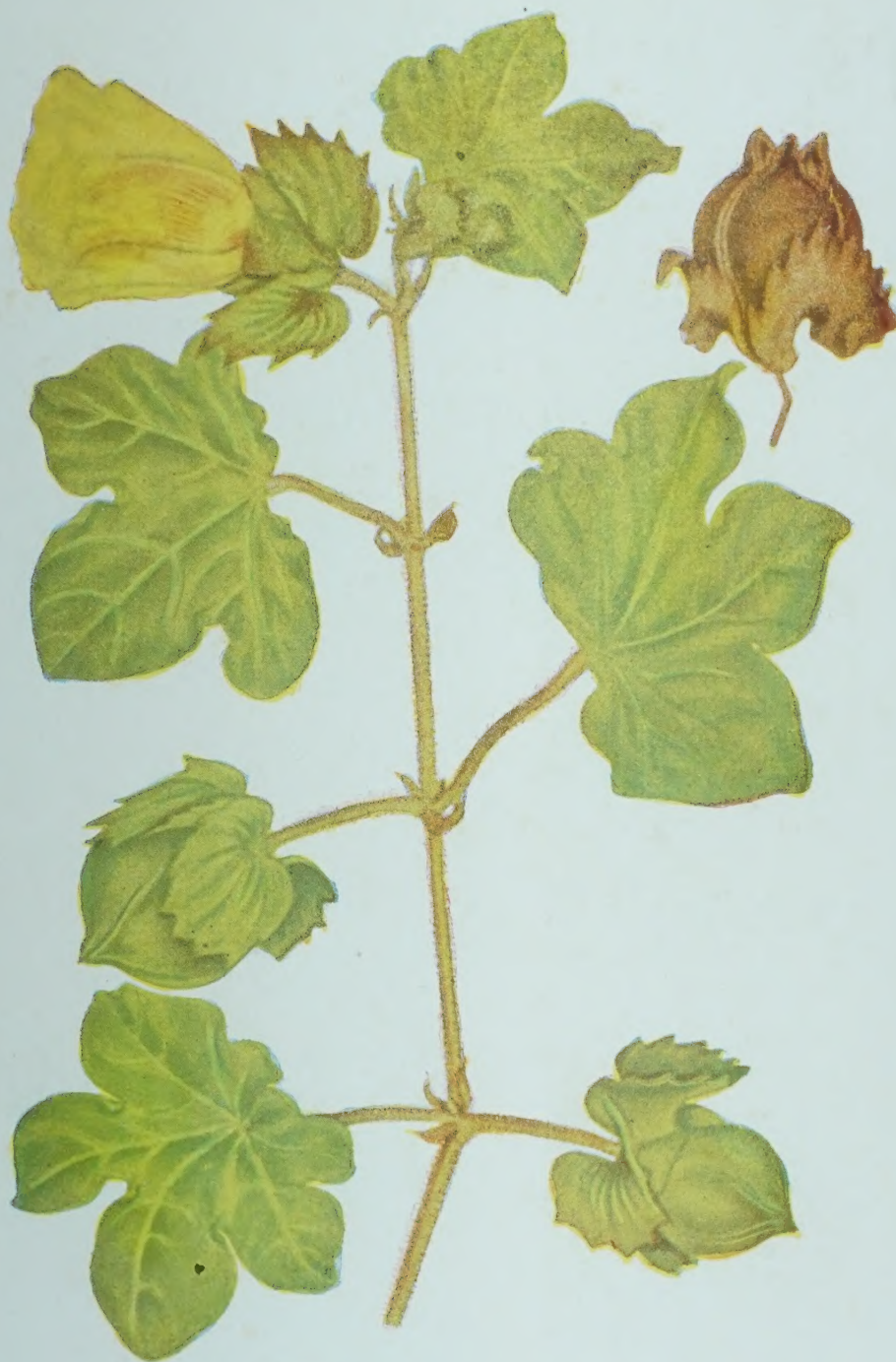
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COTTON IN INDIA

A MONOGRAPH



GOSSYPIMUM HERBACEUM RACE WIGHTIANUM

(Reproduced from Wealth of India—Raw Materials, Vol IV, CSIR, New Delhi)

COTTON IN INDIA

A MONOGRAPH

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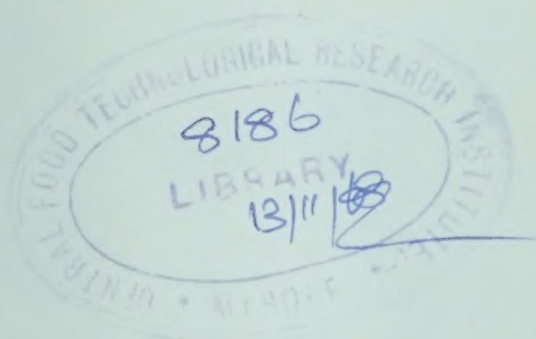
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Cotton in India.

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INTRODUCTION

It was at the 73rd Meeting of the Indian Central Cotton Committee held in February, 1956, that it was decided to publish a Monograph on Cotton in India with a view to providing the various educational and research institutions and the enlightened cotton growers with a standard book of reference giving in a simple form a comprehensive account of cotton in all its aspects on a regionwise basis. The question was subsequently considered in detail by the Monograph Sub-Committee which decided that the Monograph should consist of four volumes comprising the following chapters :

Volume I: History of Cotton ; Climate and Soils ; Taxonomy ; Morphology ; Embryology ; Breeding ; Cytology ; and Genetics.

Volume II: Physiology ; Agronomy ; Diseases ; Insect and Mite Pests ; and Seed Multiplication and Distribution.

Volume III: Technology ; Ginning and Pressing ; Marketing ; Consumption of Cotton (Seed) ; Consumption of Cotton (Lint) ; Legislative Measures ; and Exports and Imports.

Volume IV: Northern *hirsutum-arboreum* Region ; Central *arboreum* Region ; Southern *hirsutum-arboreum* Region ; Central *hirsutum-arboreum-herbaceum* Region ; Western *herbaceum* Region ; and Eastern Region.

The First Volume was, thus, issued in February, 1960.

It is a matter of deep gratification that it has been possible to bring out this Second Volume in such a short time. Needless to say, this has been greatly due to the unstinted co-operation extended by the various authors.

The present volume deals with Physiology, Agronomy, Diseases, Insect and Mite Pests, and Seed Multiplication and Distribution, materials for which have been contributed by eminent scientists in the different disciplines. I am grateful to Prof. R. H. Dastur, Dr. R. D. Asana, late Shri K. Sawhney,

Dr. S. M. Sikka, Dr. R. S. Vasudeva, Dr. Quadiruddin Khan and Dr. V. P. Rao who have taken great pains in presenting the material in a comprehensive manner for their respective chapters.

I must express my deep sense of gratitude to the President of the Indian Central Cotton Committee, Dr. M. S. Randhawa, but for whose sustained interest, the issue of this publication would not have been possible.

I am thankful to the Council of Scientific and Industrial Research for their kind permission to reproduce the coloured plate *Gossypium herbaceum* race *wightianum* appearing in the article on *Gossypium* Linn. of the 'Wealth of India—Dictionary of Indian Raw Materials and Industrial Products' and to the United States Department of Agriculture and the Madras Government for kindly according permission to reproduce some of the illustrations in the chapter on Insect and Mite Pests. One illustration in this chapter was supplied by Shri K. Dharmarajulu, which is acknowledged with thanks.

The co-operation and encouragement received from the members of the Indian Central Cotton Committee, particularly the Vice-President, Shri Madanmohan R. Ruia, Sarvashri R. G. Saraiya, Chimanlal B. Parikh and Chunilal B. Mehta are gratefully acknowledged. The staff of the Indian Central Cotton Committee connected with the Monograph work also deserve thanks for the zeal and interest with which they have worked to complete this volume.

I am thankful to Shri Prem Nath, Chief Editor, Indian Council of Agricultural Research, for the final editing of the material and for the several suggestions made concerning the publication of this volume. My thanks are also due to Shri N. S. Bisht, Director of Arts, Indian Council of Agricultural Research, for the design of the jacket and the lay out of the illustrations.

Bombay
June 1960

B. L. SETHI
Secretary
Indian Central Cotton Committee

CONTENTS

	PAGE
INTRODUCTION	iii
CHAPTER I	
PHYSIOLOGY— <i>R. H. Dastur and R. D. Asana</i>	1—105
Growth Behaviour. Physiological Chemistry. Effect of Micro-Nutrients. Effect of Application of Plant Hormones. Bud and Boll Shedding. Physiology of 'Bad Opening' of Bolls in Punjab-American Cottons. Red Leaf Disease in <i>hirsutum</i> Cottons. Physiological Causes of Low Yields. Effect of Manuring on Yield. References.	
CHAPTER II	
AGRONOMY— <i>K. Sawhney and S. M. Sikka</i>	106—163
Season of Sowing. Crop Rotation. Implements. Preparation of Soil. Method of Sowing. Seed Rate and Spacing. Cultivation After Sowing. Manuring. Irrigation, Water Conservation and Drainage. Harvesting. Cotton Yields. Improved Varieties. Seed Multiplication.	
CHAPTER III	
DISEASES— <i>R. S. Vasudeva</i>	164—216
Fungus Diseases. Bacterial and Nematode Diseases. Virus Diseases. Non-Parasitic Diseases. References.	
CHAPTER IV	
INSECT AND MITE PESTS— <i>Quadiruddin Khan and V. P. Rao</i> ..	217—301
Insect Pests. Mite Pests Cotton Boll Weevil, <i>Anthonomus grandis</i> Boheman, a Cotton Pest Not Occurring in India. List of Insect and Mite Pests of Cotton in India. Common Insect and Mite Pests of Cotton in Different States. References.	
CHAPTER V	
SEED MULTIPLICATION AND DISTRIBUTION— <i>B. L. Sethi</i> ..	302—335
Earlier Work Under Agricultural Departments. Work Under Indian Central Cotton Committee. Seed Multiplication and Distribution in States. Partition and After. First Five-Year Plan. Work Under Second Five-Year Plan. Work in Other Cotton Growing Countries.	
INDEX	336—339

LIST OF ILLUSTRATIONS

I. MAPS AND CHARTS

	PAGE
<i>Gossypium herbaceum</i> race <i>Wightianum</i>	<i>Frontispiece</i>
1. Performance of 4F Punjab-American Cotton Plants on Different Soils	2
2. Flowering Curves for American Cottons in the Punjab and Sind	18
3. Relative Growth Rate of American Cotton Plants in the Punjab and Sind	19
4. Net Assimilation Rate of American Cotton Plants in the Punjab and Sind	20
5. Percentage of Total Uptake of Various Minerals at Different Stages of Growth	21
6. Percentage of Minerals in Various Plant Parts of 4F Punjab-American Cotton	22
7. Percentage of Mineral Salts in Different Parts of 4F Punjab-American Cotton Plant	24
8. Carbohydrates in the Leaves	30
9. Carbohydrates in the Stem	32
10. Carbohydrates in the Flowering Parts	34
11. Cane Sugar in the Leaves	45
12. Starch in the Leaves	43
13. Total Dry Weight	48
14. Dry Weight of the Flowering Parts	50
15. <i>Left</i> —Flowering Parts per 100 gm. of Total Dry Weight	
<i>Right</i> —Percentage Increase in Total Dry Weights	52
16. Flowering Curve for Sind Sea Island Cotton in the Punjab	87
17. Relative Growth Rate for Sind Sea Island and Egyptian Cottons	89
18. Net Assimilation Rate for Sind Sea Island and Egyptian Cottons	90
19. <i>Above</i> —Maximum and Minimum Temperatures During the Growing Season	
<i>Below</i> —Flowering Curve for Sind Sea Island Cotton	92
20. Sowing Seasons in Different States	108
21. Meston Hindustan Plough	114
22. Pegged Harrow	114
23. Triangular Spike-Toothed Harrow	114
24. <i>Munna</i> (<i>Desi</i> Plough)	115

25.	<i>Bakhar</i> (Blade Harrow)	115
26.	<i>Guntaka</i> (Used in Madras)	116
27.	'Victory' Mould-Board Plough	117
28.	Single Row Cotton Drill	118
29.	<i>Tiphan</i> (Three-Coultered Seed Drill)	118
30.	<i>Khurpi</i> (Hand Hoe)	119
31.	Diagrammatic Field Showing Spread of Root Rot Disease	172
32.	Progress of Disease During Different Months	177
33.	Effect of Sowing Date on the Incidence of Root Rot	179
34.	Effect of Intercropping Cotton with <i>Moth</i> on the Incidence of Diesase	180
35.	Pink Bollworm (<i>Platyedra gossypiella</i> Saund.)—Infested Bolls and Stages of Growth	220
36.	Spotted Bollworm (<i>Earias insulana</i> and <i>E. fabia</i>)—Infested Parts and Stages of Growth	230
37.	Stem Borer (<i>Sphenoptera gossypii</i> Cotes)—Infested Stem and Stages of Growth	256
38.	Jassid (<i>Empoasca devastans</i> Dist.)	259
39.	Dusky Cotton Bug (<i>Oxycarenus laetus</i> Kirby)—Infested Bolls and Stages of Growth	276
40.	Cotton Boll Weevil (<i>Anthonomus grandis</i> Boheman)—Infested Parts and Stages of Growth	282
41.	Production of Cotton Under Different Staple Length Groups	318
42.	Area Under Cotton During First Five-Year Plan	321
43.	Production of Cotton During First Five-Year Plan	322
44.	Production of Cotton During Second Five-Year Plan	324
45.	Centres of Cotton Seed Distribution	326
46.	Progress of Improved Varieties of Cotton	328
47.	Percentage of Area Under Improved Varieties	331
48.	Additional Income Due to Cultivation of Improved Varieties	332

II. PLATES

Ia.	Changes in Morphological Characters of American Cotton Plant by 2,4-D	65
Ib.	Section of Leaf Showing Normal Chloroplasts	65
IIa.	Section of Leaf Showing Large Starch Grains in Chloroplasts	66
IIb.	Section of Leaf Showing Thick 'Tannin' Deposits	66
IIc.	'Tannin' Test in Extracts of Leaves	66
IIIa.	Normal Cotton Crop Showing Erect and Turgid Condition of Leaves	67

IIIb.	Cotton Crop on Soil with Saline Sub-Soil Showing Drooping Leaves	67
IVa.	May-Sown Cotton Crop on Sandy Loam with Saline Sub-Soil Showing 'Badly Opened' Bolls	68
IVb.	June-Sown Cotton Crop on Sandy Loam with Saline Sub-Soil Showing 'Well Opened' Bolls	68
V.	Improved Seed Drill Operated by Bullock Power	149
VI.	Planet Junior Hoe Being Worked Between the Ridges in Cotton Field	150
VII.	A Field of Surat Cotton	151
VIII.	Picking of Cotton	152
IXa.	An Infected and Healthy Plant Showing Surface of Wood ..	201
IXb.	Cotton Field Infected with Root Rot	201
IXc.	Cotton Roots Affected with Root Rot in an Advanced Stage	201
Xa.	Control of Disease by Intercropping with <i>Phaseolus aconitifolius</i>	202
Xb.	Cotton Bolls Affected with Anthracnose	202
Xc.	Cotton Leaf Affected with Angular Leaf Spot	202
XIa.	Roots of Cotton Plant Showing Knots Caused by <i>Meloidogyne incognitia</i> var. <i>acrita</i>	203
XIb.	'Small Leaf' Affected Plant and A Healthy Plant	203
XIc.	Affected Cotton Leaves with Reduced Size and Different Kinds of Lobes and Normal Leaves	203
XIIa.	Field of Cotton Showing Drooping Leaves due to Water Shortage	204
XIIb.	Normal Cotton Crop with Erect and Turgid Leaves	204
XIII.	Leaf Roller (<i>Sylepta derogata</i> Fabr.)—Infested Leaves and Stages of Growth	269
XIV.	Leaf Worm (Semilooper)—Infested Parts and Stages of Growth	270
XV.	Stages of Infestation by Stem Weevil (<i>Pempheres affinis</i> Fst.) ..	271
XVI.	Aphid (<i>Aphis gossypii</i> Glov.)—Infested Parts and Stages of Growth	272

CHAPTER I

PHYSIOLOGY

Cotton has been studied in India largely from the breeding point of view as it is the most important cash crop in the country. Very little attention has, however, been paid to the study of its physiological aspects.

The Indian Central Cotton Committee financed a scheme in 1925 to study the causes of bud and boll shedding in *herbaceum* cottons grown in Gujerat (Bombay State). Subsequently physiological research on *hirsutum* (American) cottons in Sind was undertaken to study their behaviour under irrigated conditions, before the waters of the Indus were made available for irrigating the crop in the southern parts of the Province. Later, a scheme was sponsored to study the causes of periodic partial failures of American cottons in the western areas of the Punjab (now Pakistan). The results obtained from that scheme led the Indian Central Cotton Committee to finance a number of other physiological research schemes. These are now in operation in Madhya Pradesh at Indore, and in Mysore State at Dharwar, Bangalore and Mandya.

The work done under the above schemes is of an applied nature. No fundamental physiological research has, however, been attempted so far, as all attention has been concentrated mostly on the physiological causes of bud and boll shedding, 'bad opening' of bolls with immature seeds and lint, premature yellowing and reddening of leaves, low yields of seed cotton, etc. However, some results of a fundamental nature have been obtained while investigating these causes. This chapter is based on these findings.

GROWTH BEHAVIOUR

RELATIVE GROWTH RATE AND NET ASSIMILATION RATE

Growth studies on the cotton crop have been undertaken from time to time under different conditions of soil and climate. These studies were started first on the Punjab-American and Sind-American cottons grown under irrigated conditions, and were later extended to the rainfed tracts of Malwa in the erstwhile State of Madhya Bharat and Gujerat area where cotton is grown as a *kharif* crop. Similar studies were taken up in Dharwar-Gadag area where cotton is grown partly as a *kharif* crop and partly as a winter crop. The main findings from these studies are summarised below.

The study was first undertaken in the Punjab on 4F Punjab-American cotton grown on sandy loam and light sandy soils. The sub-soil in both

cases may or may not contain free sodium salts. It may be mentioned that as *tirak* or 'bad opening' was found to be associated with light sandy soils and on soils with saline sub-soils, the growth studies were undertaken on these soil types. The subject of *tirak* is dealt with in a separate section.

The study which spread over three years revealed that there were no major differences in the growth trends of plants in all the four soil types (Fig. 1). There was a depression in the relative growth rate and in the net assimilation rate in the months of August and September on sandy loam with saline sub-soils. This depression might have arisen as a result of the plants suffering from a water deficit on account of the inability of the roots to absorb enough moisture from saline sub-soils.

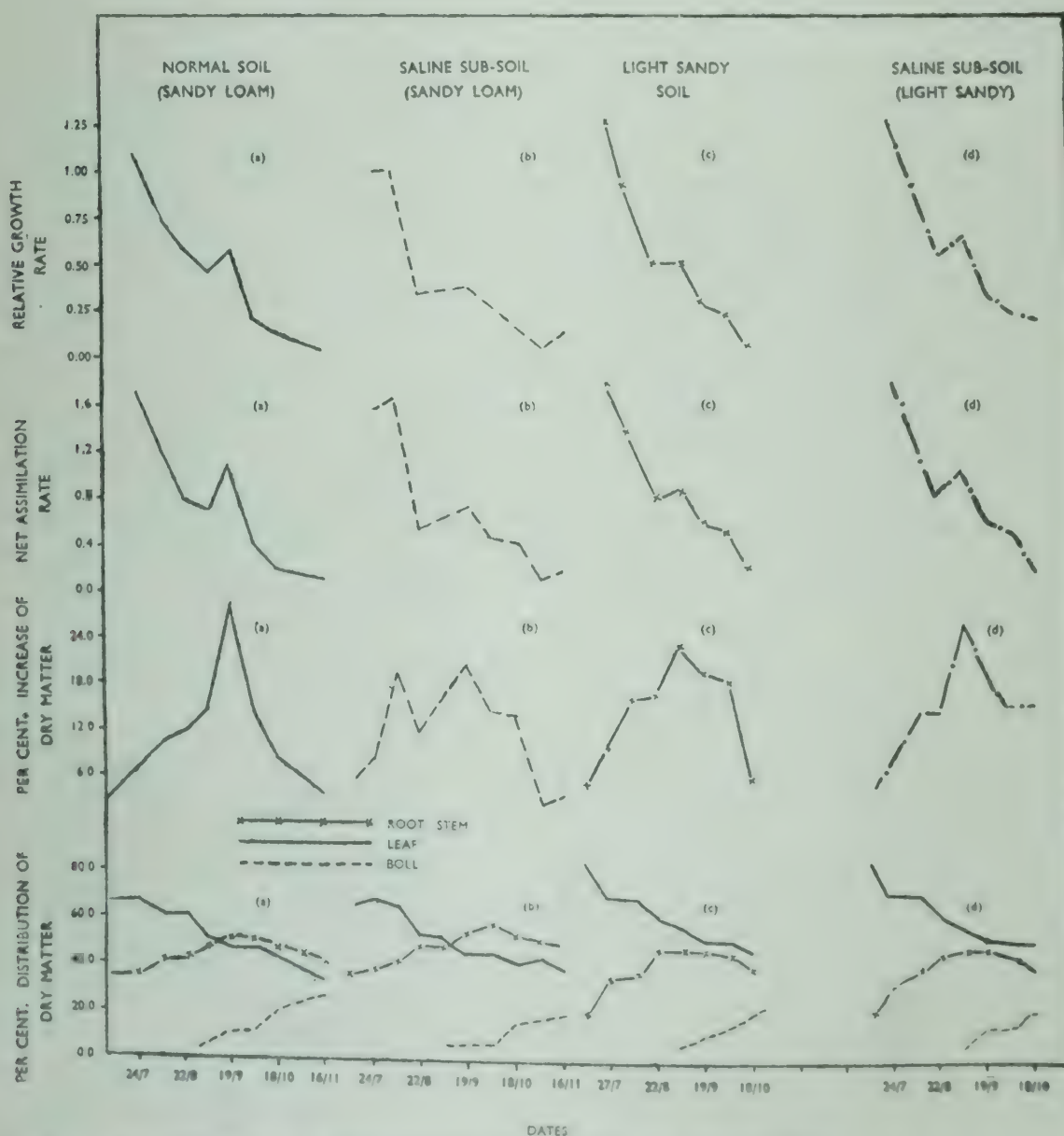


Fig. 1. Performance of 4F Punjab-American Cotton Plants on Different Soils

The relative growth rate and net assimilation rate were higher in the early stages of growth in light sandy soils than in the normal sandy loams. But the limiting influence of nitrogen factor became visible in the growth curves in September and October when the relative growth rate and the net assimilation rate became lower than those of the plants in normal sandy loam.

The maximum percentage increase in dry matter occurred generally by the middle of September (the usual sowing time being the middle of May) on all types of soils except on sandy loams with saline sub-soils where no definite maximum was visible. The curve for the latter type of soil was very irregular as the crop suffered from a water deficit between two successive irrigations.

When the percentage of distribution of dry matter in the different organs of the plants on the four types of land was studied, it was found that the percentage of dry matter in the bolls was higher on normal sandy loam than on the other three soils where *tirak* occurred. Another important difference was in the distribution of dry matter in the stems and leaves. On sandy loams the stems contained a larger percentage of dry matter per plant than the leaves did, while on light sandy soils there was more dry matter in the leaves than in the stems.

Similar growth studies on *hirsutum* cottons (Dharwar-American ; Indore 1) in the rainfed tracts of Malwa at Indore, where cotton sowings were done as soon as the first rains were received, showed important features. The plants registered rapid growth in extension during the first 100 days after sowing, irrespective of the sowing date. The growth was more vigorous in the pre-monsoon sown crop than in the rain-sown one, on account of the development of a vigorous root system under the high temperature and optimum soil conditions that prevail in Malwa before the monsoon breaks.

TABLE 1. RELATIVE GROWTH RATE AND NET ASSIMILATION RATE OF UNMANURED PLANTS

Place	Monthly Relative Growth Rate of Plant						
Surat (Gujerat)	0.910	2.630	1.500	1.100	0.390	0.420	0.300
	Fortnightly Relative Growth Rate of Plant						
Indore (Malwa)	0.690	0.511	0.600	0.353	0.100	0.180	-0.047
Lyallpur (Punjab)	1.720	1.070	0.810	0.098	0.353	0.110	0.151
	Gm. per Gram of Leaf (N. A. R.)						
Surat (Gujerat)	1.150	3.630	2.220	1.670	0.710	1.000	0.600
Indore (Malwa)	0.970	0.700	0.867	0.700	0.481	0.691	0.220
Lyallpur (Punjab)	2.300	1.550	1.300	-0.100	0.700	0.000	-0.350

The increase in the dry matter during the first 100 days after sowing was small as the temperatures dropped considerably soon after the first rains

were received and the cloudy conditions contributed to a decrease in photosynthetic activity. But later the crop gained in dry weight at a more rapid rate as soon as the weather conditions became more favourable. The differences in the relative growth rate and the net assimilation rate between the crops in the irrigated tracts of the Punjab and those in the rainfed areas of Malwa and Gujerat can be seen from Table 1.

The relative growth rate as well as the net assimilation rate was higher in the Punjab than at Indore or Gujerat and these caused considerable differences in the total dry matter produced per plant in these tracts.

EFFECT OF NITROGEN ON GROWTH

A detailed study was made on the growth of the cotton plant in several experiments conducted in the Punjab, Sind, Madhya Pradesh and Gujerat. These experiments comprised the study of the effect of different combinations of nitrogen, potash and phosphoric acid. Generally, potash and phosphorus were found to have no effect while nitrogen proved to be the most potent factor under the Punjab and Gujerat conditions. The leaf growth rate, the relative growth rate and the net assimilation rate were high during the important stages of growth but that was not the case under the rainfed conditions of the Malwa tract where no consistent effect of nitrogen on these characters was visible. There was a difference, both in the relative growth rate and the net assimilation rate, when the rainy weather set in, between the plants manured with nitrogen and in the unmanured crop (Table 2).

TABLE 2. EFFECT OF NITROGEN ON RELATIVE GROWTH RATE AND NET ASSIMILATION RATE OF MANURED PLANTS

Place		Monthly Relative Growth Rate of Plant						
Surat	1·10	3·79	1·32	0·72	0·50	0·11	0·20	
<i>Fortnightly Relative Growth Rate of Plant</i>								
Indore	0·72	0·50	0·59	0·43	0·18	0·18		
Lyallpur	1·50	1·15	1·00	0·25	0·36	0·00	0·05	(—)0·05
<i>Effect of Nitrogen on Net Assimilation Rate in Gm. per Gram of Leaf</i>								
Surat	1·71	5·20	2·35	1·42	1·09	0·78	0·50	
Indore	0·95	0·65	0·92	0·75	0·36	0·45	0·22	
Lyallpur	1·80	1·85	1·51	0·58	1·57	0·62	0·78	(—)0·35

It appeared that nitrogen treated plants grew more vigorously during the early stages soon after sowing, after which a depression in the rate of growth occurred (compare Tables 1 and 2). During the latter stages the unmanured plants were found to grow more vigorously than the manured plants.

The net assimilation curve showed a steep fall in the Punjab from the very beginning of the growth while similar curves under Malwa conditions showed some rise and fall owing to the spells of rainy conditions during the growth period.

Application of nitrogen was found to increase the meristematic activity, growth in extension and dry matter in all the tracts where investigations were conducted. It was also found to influence the reproductive characters such as the flower production, boll number per plant and boll weight. It also increased the yield of seed cotton per acre. These facts can be seen from Table 3. They have been verified in a number of experiments (Dastur, 1946; Dastur and Mukhtar Singh, 1943; Dastur and Gopani, 1952 and Dastur and Kanwar Singh, 1956).

TABLE 3. EFFECT OF NITROGEN ON VARIOUS CHARACTERS IN DIFFERENT TRACTS

Dose of nitrogen (lb. per acre)	Height (cm.)	Dry Weight (gm. per plant)	Total no. of flowers per plant	Boll no. (per sq. yard)	Boll weight (gm.)
PUNJAB					
0	100.4	312.0	97.8	51.81	1.78
50	121.4	446.6	149.8	68.46	2.06
MALWA					
0	49.7	21.7	6.0	12.3	2.34
33	58.0	28.3	—	19.1	2.50
66	63.1	34.2	—	24.7	2.67
SURAT					
0	81.6	94.5	38.6	15.0	2.18
50	91.4	132.4	66.0	26.4	2.49

EFFECT OF SPACING ON GROWTH

The *tirak* disease in the Punjab was avoided by adopting late sowings; it was, therefore, necessary to examine the problem of spacing in relation to sowing date as there is a reduction in boll number per plant by late planting. Results of investigations on this aspect of spacing in combination with sowing date have already been published by Dastur and Mukhtar Singh (1949). When the plants were widely spaced the growth in extension as well as the dry matter per plant was significantly greater than when spaced closely. This was to be expected due to the greater availability of light, nutrients, water, etc. The same relation held good in case of the flower or boll production per plant and per square yard.

Consistently higher dry weights per square yard have been obtained with close spacing as compared with wide spacing in all the sowings, while in case of reproductive development close spacing has benefitted the late sowings only. This shows that surplus dry matter, beyond a certain maximum, is ineffective and plays no vital role in the economy of the plant. Wide spacing and late sowings produce plants which are, weight for weight, efficient for production of seed cotton (*kapas*). The smaller the size of the plant the greater is its efficiency for the production of seed cotton. At the same time it may be pointed out that though late sown and widely spaced plants possess the maximum efficiency, compensation is inadequate under this treatment. Thus, below a certain maximum dry weight, gain in

efficiency fails to cover the loss in yield caused by reduced bearing due to the small size of the plants.

Nitrogen and Spacing. It was found that nitrogen acted as a limiting factor in case of close spacing since minimum values for all growth measurements per plant were obtained when nitrogen was not applied while wide spacing or nitrogen stimulated elongation as well as the production of dry matter. Of the two factors, 50 lb. nitrogen per acre was found to be more effective. There were further increases in height and dry matter when nitrogen was applied to widely spaced plants. But before considering the magnitude of such increases it is necessary to bear in mind that widely spaced plots contain less plants per unit area in comparison to those of close spacing. As manure is applied at a uniform rate in pound per acre the individual plant under wide spacing gets proportionately large dose of manure as compared with an individual under close spacing. In spite of this privilege widely spaced plants derived only as much benefit in the production of dry matter from nitrogen application as the closely spaced plants. The effect was more pronounced in case of height and internodal length where widely spaced plants distinctly responded less than the closely spaced plants. There was thus a clear indication of a diminished utility of nitrogen with wide spacing. This was further confirmed when the data for dry weight were considered on area basis. The close spacing which produced greater dry matter in the absence of nitrogen produced better results when nitrogen was applied.

Essentially the same relations were seen to hold in case of yield and yield characters (Table 4). Although nitrogen affected the flowering, boll number and yield significantly under either of the two spacings, the magnitude of response was distinctly larger with the close spacing.

TABLE 4. INTERACTION OF NITROGEN AND SPACING

<i>Flowers per sq. yard</i>					<i>Bolls per sq. yard</i>				
		<i>s</i> ₁	<i>s</i> ₂	Diff.			<i>s</i> ₁	<i>s</i> ₂	Diff.
<i>O</i>	..	168	149	+9.99	<i>O</i>	..	45.4	40.7	+2.81
<i>n</i>	..	266	213	-19	<i>n</i>	..	64.2	56.4	-4.7
Diff.				-53	Diff.				-7.8
+9.99	..	+99	+64		+2.81	..	+18.2	+15.7	
<i>Boll weight in gm.</i>					<i>Yield in mds. per acre</i>				
		<i>s</i> ₁	<i>s</i> ₂	Diff.			<i>s</i> ₁	<i>s</i> ₂	Diff.
<i>O</i>	..	1.29	1.40	+0.065	<i>O</i>	..	7.68	8.22	+0.69
<i>n</i>	..	1.67	1.56	+0.11	<i>n</i>	..	14.95	12.95	+0.54
Diff.				-0.11	Diff.				-2.01
+0.065	..	+0.38	+0.16		+0.69	..	+7.27	+4.27	

*s*₁=close spacing, *s*₂=wide spacing.

n=50 lb. nitrogen per acre.

In their studies on the growth of American cottons in Malwa tract, Dastur and Kanwar Singh (1956) have conducted extensive trials on the effects of spacings on Indore 1 and Family 2 (Malvi cotton). The cotton crop in this tract is generally sown in rows 14 to 24 inches apart.

In the past no special study had been made regarding the optimum spacing for the cotton sown on different dates. Experiments were conducted for a study of single factor only and, therefore, no information was available on the inter-relation of these factors. Out of several multifactor experiments conducted the inter-relationship of spacing with the sowing date and nitrogen only have been summarised here.

TABLE 5. EFFECT OF SPACING ON VEGETATIVE AND REPRODUCTIVE CHARACTERS

Experiment No.	Square feet spacing per plant						C.D. 5%
	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	3	4	

		<i>Dry Weight per Plant in gm.</i>					
I	—	27.1	28.8	30.7	31.8	33.6	5.23
V	25.5	28.2	30.4	—	—	—	2.32
VI	41.0	48.0	—	51.2	—	—	8.69
		<i>Dry Weight per sq. Yard in gm.</i>					
I	—	244	173	147	96	80	38.62
V	457	254	184	—	—	—	32.14
VI	693	432	—	321	—	—	14.98
		<i>Bolls per Plant</i>					
I	—	2.71	3.63	4.02	4.42	—	0.38
V	1.66	2.50	2.91	—	—	—	0.10
VI	2.50	3.59	—	4.70	—	—	0.13
		<i>Bolls per sq. Yard</i>					
I	—	24.5	26.5	20.1	13.3	—	2.40
V	21.8	18.4	16.0	—	—	—	2.69
VI	45.0	32.4	—	21.2	—	—	4.06

The spacing showed, as in the Punjab, considerable effect on the production of dry matter; the dry matter per plant increased as the spacing became wider on account of better growth of the plant. When the production of dry matter was considered on the basis of unit area, the reverse condition was again obtained (Table 5). The compensatory growth due to wider spacing did not cover the loss in the number of plants. This effect of spacing both on dry weight per plant and per unit area, therefore, came out to be significant. The greater production of dry matter per unit area under close spacing further indicated that the supply of nutrients was not limited under close spacing and a widely spaced crop did not, therefore, fully utilise the nitrogen and other nutrients available from the soil.

There was a significant increase in the number of bolls produced per plant as the spacing became wider. On unit area basis quite the opposite trend was again indicated. Close spacing produced a significantly larger

number of bolls per unit area than wider spacing did. Thus from the yield point of view, close spacing was superior to wide spacing.

There was also a progressive rise in the value of fruiting coefficient as the spacing became wider. Thus if more space was available, the efficiency of the plant increased for the production of seed cotton. Wider spacing means greater efficiency, while closer spacing gives rise to higher yield per unit area, though the efficiency for the utilisation of the vegetative growth for crop production was lowered. Fruiting coefficient was found to increase significantly in five cases out of seven (Table 6).

TABLE 6. EFFECT OF SPACING ON FRUITING COEFFICIENT

Experiment No.	Square feet						C.D. 5%
	$\frac{1}{2}$	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	3	
I	—	—	0.18	0.24	0.24	0.25	0.063
V	—	0.16	0.23	0.24	—	—	0.026
VI	—	0.16	0.20	—	0.23	—	0.040
VIII	0.17	0.24	0.30	0.32	—	—	0.022
IX	—	0.30	0.32	—	—	—	0.027
X	—	0.21	0.22	—	—	—	—
XII	—	0.22	0.29	—	—	—	0.073

The interaction between sowing date and spacing came out to be significant in three experiments out of five. In all the experiments there was a greater increase in boll number per plant with wider spacing which began to decrease with the delay in sowing date. The early sown plants were benefitted more by wider spacing than the late sown crop. On unit area basis, however, there was a greater increase in boll number with closer spacing and early sowing in three experiments out of five.

TABLE 7. INTERACTION OF SPACING AND NITROGEN—INCREASE IN BOLLS PER PLANT OVER UNMANURED PLANTS UNDER DIFFERENT SPACINGS

Experiment No.	Dose of nitrogen (per acre)	Very close	Close	Medium	Wide	C.D. 5%
V	33	—	+0.67	+0.82	+1.10	0.174
	66	—	+1.20	+1.43	+1.76	—
VI	33	—	+0.73	+1.38	+0.16	0.229
	66	—	+1.36	+1.14	+0.84	—
VIII	50	+0.23	+0.63	+0.72	+0.85	—
IX	50	—	+0.79	—	+1.05	—
X	50	—	+0.49	—	+0.64	—
XII	33	—	+0.81	—	+0.87	—

The increase in boll number per plant due to nitrogen was higher in wide spacing in five experiments out of six. The reverse was the case when considered on an area basis and the number of bolls decreased with the

increase in spacing. The increase in boll number per plant was, therefore, not able to compensate for the greater number of plants per unit area. Close spacing, therefore, gave large increases in the boll number with manuring than with wider spacing and was consistently superior irrespective of other treatments. In the present case, therefore, a closer spacing of half square foot not only gave a higher boll number but also gave consistently larger response to nitrogen (Table 7).

Effect of Spacing on Yield. The level of yield can be substantially increased by adopting closer spacing than the normally adopted spacing of $1\frac{1}{2}$ to $2\frac{1}{2}$ feet between rows. This was an important result for this tract.

The yields under different spacings obtained in seven experiments are given in Table 8.

TABLE 8. EFFECT OF SPACING ON YIELD OF SEED COTTON*

Experiment No.	Square feet spacing per plant						C.D. 5%
			1	1	2	3	
I	—	—	3.99	3.90	3.20	2.56	0.42
V	—	7.01	6.01	5.31	—	—	0.94
VI	—	10.09	7.57	—	5.89	—	1.17
VIII	3.72	4.11	3.36	2.82	—	—	0.23
IX	—	5.12	3.66	—	—	—	0.53
X	—	1.87	1.36	—	—	—	0.66
XII	—	9.91	7.20	—	—	—	0.69

* Maunds per acre.

Half square foot per plant equivalent to 9 inches between rows and 8 inches between plants or 12 inches between rows and 6 inches between plants was found to be the optimum spacing; spacing closer than half square foot per plant was found to reduce the yields.

Cumulative Effect of Sowing Date and Spacing. The effect of spacing on the early sown and the late sown crop on yield was determined in five experiments (Table 9).

TABLE 9. YIELD OF SEED COTTON

Experiment I				Experiment IV			
Spacing	Sowing dates			Spacing	Sowing dates		
	d ₁ 12/5	d ₂ 1/6	d ₃ 14/7		d ₁ 28/5	d ₂ 8/6	d ₃ 29/6
Close	3.94	6.51	0.67	Close	16.23	12.62	1.43
Medium	4.17	5.36	0.66	Medium	10.49	11.49	0.73
Wide	3.34	4.10	0.39	Wide	9.62	7.25	0.31
Close-medium	+0.23	+1.15	+0.01	Close-medium	%5.74	%1.13	%0.70
Medium-wide	+0.60	+2.41	+0.28	Medium-wide	+6.61	+5.27	+0.62
C.D. 5% interaction		0.73		C.D. 5% interaction		1.99	

In all the experiments, closely spaced crop whether sown early or late with rains gave significantly high yields. The results of these experiments were in favour of the necessity of adopting close spacing even when the crop was sown early before the rains.

Thus close spacing of the crop was an absolute necessity under all conditions of sowing date and manuring.

The results obtained in Malwa regarding the interaction of sowing date with spacing on yield differed from those obtained in the Punjab (Dastur and Mukhtar Singh, 1944) where close spacing was found beneficial only for the late sown crop. The interaction of sowing date and spacing was, therefore, significant in the Punjab. In Malwa, the magnitude of the increase from adopting closer spacing was greater in the case of early sowings than in late sowings.

This difference in the relation of sowing date with spacing can be attributed to the difference in the vegetative structure of the cotton plant in two tracts. The early sown cotton crop in the Punjab produced a very vigorous and dense growth. The close spacing was, therefore, not at all necessary as the ground was covered fully by widely spaced crop. That was not the case at Indore where the vegetative growth produced, even by early June-sown crop, was small and closer spacing was found more necessary than the normal practice, even for early sowings to cover the soil.

Cumulative Effect of Spacing and Nitrogen. The relation of spacing to nitrogen on yield was studied in six experiments and in all cases it was found that the highest yields were obtained as a result of manuring on closely spaced crop.

Whenever the crop was manured either with 33, 50 or 66 lb. nitrogen per acre the highest yields were registered in the closest spacing of half square foot per plant on both the soil types. It is, therefore, very necessary that close spacing should be adopted to derive the maximum benefit when manure is applied to the soil.

Thus early sowing, close spacing and manuring proved to be the best combination for growth and yield under the rainfed conditions of Malwa tract.

In Surti cotton (*G. herbaceum* var. *acerifolium*, Guill., etc., Perr.) the spacing had altered considerably. It was first sown 2 feet apart but this practice was changed in 1923-24 on the Government Farm and cotton was dibbled at 3 feet by 3 feet. In 1932, cultivators on their own initiative started sowing cotton at distances of 4, 5 and 6 feet between rows and thinned to 1 foot to 1½ feet as they found that wider spacing resulted in better yields. Even at present cotton in Surat district is sometimes sown at 8 feet distance between rows.

In order to get experimental evidence for the optimum spacing requirements of this cotton, experiments were conducted at the Agriculture Farm,

Surat, in two series, one from 1932 to 1937 and the other from 1939 to 1945. In conducting these experiments, the term wider or closer spacing was referred only to the distance between rows, irrespective of plant to plant distance. In the first and second series the closest spacing was kept at 3 feet between rows but the plant distance was different in the two series. In the first series it was 3 feet between plants and in the second series it was 1 foot between plants. Thus the unit area per plant was 9 square feet in the first series and 3 square feet per plant in the second series. The wide spacing was 12 square feet (6' x 2') per plant in both the series. It was on account of this difference between the close spacings in the two series that the yields under close and wide spacings in the first series were nearly equal ; while, in the second series the difference between the yields in wide and close spacings was significant, the former yielding higher than the latter. Thus, in the first series the yields between 9 square feet per plant and 12 square feet per plant were equal while in the second series the yields under 12 square feet per plant spacing were higher than under the spacing of 3 square feet per plant. This indicated that close spacing of 3 square feet per plant had proved harmful. The observation made on the spacing experiment laid out in 1942-43 cotton season suggested that, the closely spaced crop appeared to suffer from a deficiency of nitrogen as the growth of the crop was stunted and the leaves were smaller in size, some of which showed yellowing at the margins.

Mere determination of yields in a spacing experiment did not throw light on the physiological causes of lower yield under closer spacing, even though plant population per acre was considerably increased when close spacing was adopted. A study of the physiology of growth and the mineral uptake was, therefore, undertaken by Dastur and Gopani (1952), to determine in what respects the growth as a whole was affected under close spacing.

Final height, dry weight, boll number, boll weight, yield, earliness index and fruiting coefficient were recorded.

A study of the results of the final height per plant and the dry weight per unit area under different spacings indicated that the height per plant significantly increased, as the spacing became wider, while the dry weight per unit area (square yard) was greater in closer spacing than under wider spacing, even though the dry weight per plant increased significantly as the spacing became wider.

Though application of nitrogen significantly increased the height per plant and the dry matter per unit area, the same differences between spacings, were maintained.

Close spacing was, however, found to be detrimental to reproductive growth. The flower and boll production were reduced under close spacing of 4 square feet per plant.

That may be due to the greatly reduced number of bearing points, partly caused by a reduction in height and partly due to reduction in light intensity caused by the crowding of the plants.

Application of nitrogen increased the flower production under all spacings but there was no evidence of a greater increase by nitrogen application in close spacing than under wide spacing indicating that nitrogen was still deficient even under wider spacing.

The boll production per unit area under different spacings did not show the same trend. The boll production did not differ much under close and wide spacings. It was significantly less in the closest spacing in one experiment. Nitrogen, however, considerably increased boll production in all the experiments.

Though boll production did not show consistent trends in favour of wider spacing, the yields were generally found to increase as spacing became wider. This was found to be the case both in the unmanured and manured crops.

Application of nitrogen significantly increased the yields under all spacings indicating its deficiency under the soil conditions of Gujarat. All spacings were found to be benefitted equally by the application of nitrogen up to 75 lb. per acre, but under higher doses the increases in yield under wider spacing began to diminish and the yields tended to be nearly equal under close, medium and wide spacings. Thus close spacing appeared to obtain all its nitrogen requirements when very high doses of nitrogen were applied, while for wider spacings, higher doses became in excess of the requirements of the crop and probably remained unutilized. These conclusions were supported by the nitrogen analysis of the leaves (Table 10).

TABLE 10. YIELD AND NITROGEN CONTENT OF LEAVES UNDER DIFFERENT COMBINATIONS OF SPACING AND NITROGEN

Spacing per plant	Yield (lb. per acre)				Spacing per plant	Per cent. nitrogen in leaves			
	4 sq. ft.	8 sq. ft.	12 sq. ft.	Mean (± 16.04)		4 sq. ft.	8 sq. ft.	12 sq. ft.	Mean (± 0.025)
Control	323	355	357	345	Control	1.75	1.76	1.88	1.80
50 lb. N	346	375	397	374	50 lb. N	1.69	1.80	1.91	1.80
100 lb. N	416	417	425	419	100 lb. N	1.71	2.06	2.16	1.97
Mean (± 16.04)	362	384	393	379	Mean (± 0.025)	1.72	1.87	1.98	—

The concentration of nitrogen was generally higher in the leaves of widely spaced crop than in the leaves of plants of closely spaced crop. Manuring with nitrogen also generally increased the nitrogen contents of the leaves though the differences between nitrogen contents of the leaves of close and wide spacings were still maintained.

Thus from the physiological point of view close spacing of 4 square feet per plant was unsuitable under Gujarat conditions. The medium spacing

of 8 square feet per plant was also not found to be as good as 12 square feet or 16 square feet per plant spacing as the reproductive growth appeared to be slightly reduced. Twelve square feet per plant proved to be the optimum spacing as a further increase in spacing did not further increase the reproductive growth. The wider spacing incidentally possessed other advantages from a cultivator's point of view. These were; rapid completion of sowings, lesser seed rate and greater ease in interculturing.

It appeared that besides nitrogen, there was another factor that operated in producing slightly lower yields under closer spacing than under wider spacing, even under the conditions of heavy manuring. Observations on the plants showed that a very great suppression of the growth of the roots under close spacing even when nitrogen was applied occurred while the root growth was very extensive and vigorous under wide spacing. The suppression in the root growth would adversely affect the growth of the shoot and consequently of the reproductive branches.

The higher yields under wider spacing may also be caused by the slightly bigger boll produced. The boll weight was found to increase significantly in some experiments as spacing became wider while in other experiments the trends were in favour of wider spacing even though they did not register a high level.

As reproductive growth was suppressed while the dry matter production increased or remained unchanged under close spacing, the fruiting coefficient was lower under closer spacing than under wider spacing. It increased considerably as the spacing became wider.

EFFECT OF SMALL CLIMATIC DIFFERENCES ON GROWTH

The date of the appearance of the first flower bud on the cotton plant can be regarded as one of the most important physiological characters as the arrival of the crop is determined by the date of the first flower. If the early or late arrival of the crop can be known in advance, it should prove of great commercial importance. It is, therefore, necessary to study the effect of climatic conditions on the date of the formation of the first flower bud. The sowing time was another likely factor that may influence the appearance of the first flower bud and this inter-relationship between the sowing date and first bud formation must, therefore, be investigated. It was already known in Egypt (Balls, 1919) and in the Punjab (Dastur, 1946) that the dates of the first flower bud and of the crop arrival did not much differ in crops sown on different dates but as the small differences are of importance they must be precisely determined.

It generally takes about two to three months from the formation of the first flower bud to the bursting of the boll and this period is marked by two development stages: (i) square period, i.e., the time taken by a bud to open into a flower; and (ii) boll period, i.e., the time taken by an

open flower to develop into an open boll. In order to have a correct estimate of the crop arrival it is, therefore, necessary to determine the time taken by a bud to develop into a flower and the time taken by a flower to develop into an open boll under different conditions of climate and sowing time.

It is possible that the different varieties of cotton grown in a tract may differ from one another in bud initiation period, square period and boll period. The development periods of squares and boll were studied by Loomis (1927) and later by Ludwig (1931). Ludwig (1931) determined these periods for five varieties of Upland cotton in South Carolina and it was found that the square period varied from 22 to 26 days and the boll period ranged from 54 to 65 days. The seasonal difference for the square period was found to be four days and for the boll period four to eleven days. The application of a fertilizer or spacing of cotton was found to have no effect on these periods. Balls (1919) also found that boll period was a specific character. It was found to vary in different varieties. The range of variation was 42 to 51 days.

Lambert (1925-26) found in the Sudan that there was a considerable change, during the season, in the boll period ranging from 44 to 77 days. Zaitzev (1927) found a highly negative correlation between maturation period and temperature. Crowther (1944) found in the Sudan an average maturation period of 65 to 68 days. The maturation period was shorter in Egypt than in the Sudan and this difference was attributed to the higher temperatures in Egypt than in the Sudan during the two months of active bolling period.

The percentage of buds that normally develop into flowers and the percentage of flowers that develop into bolls in the different varieties are important physiological characters, and it would be useful to determine the bud and flower success of each variety as affected by the climate and sowing time. An attempt was also made to determine the effect of small differences in the climatic conditions on the development of these physiological characters in the same varieties of American cottons grown in the two different tracts, viz., South Sind and the Punjab (Dastur, 1950).

The main differences in temperature and humidity between the two tracts are: (i) early drop in temperature in Hyderabad (Sind) in July; (ii) higher minimum temperatures during the maturation of the crop in September and October in Hyderabad (Sind) while the latter half of the maturation period of the crop in the Punjab was characterised by falling minimum temperature from October to January; and (iii) higher humidity at day time in South Sind.

Three Punjab-American varieties, 289F/124, 289F/199 and L.S.S., and two Sind-American varieties, M.4 and Sind Sudhar, were experimented upon. It would be interesting to know how Sind-American cottons behaved under the Punjab conditions and the Punjab-American cottons under Sind conditions.

At each centre four sowing dates were kept as separate treatments in order to study the effect of sowing time on the development of various characters.

The first difference noticed between the two tracts was with regard to the development of the first fruiting branch which in the case of early varieties appeared in the axil of 6th or 7th leaf and in the axil of 8th or 9th leaf in the case of the late varieties. In the Punjab the first fruiting branch appeared at a still higher node. The first fruiting node was higher by six nodes in the early varieties and by 20 nodes in the late varieties. Thus the American *hirsutum* cotton in Sind behaved like the Egyptian cotton in Egypt (Crowther, 1944) while under the Punjab conditions the first fruiting branch appeared at a much higher node as was the case in the cottons grown in the Sudan (Tables 11 and 12).

TABLE 11. DIFFERENT PHYSIOLOGICAL CHARACTERS OF FIVE PUNJAB-AMERICAN AND SIND-AMERICAN VARIETIES (means of four sowing dates)

Variety	First fruiting node	Number of days after sowing for first bud to appear	Square period	Setting percentage of buds into flowers	Setting percentage of flowers into bolls	Boll period	Number of days after sowing for first open boll
SOUTH SIND							
M.4	6.5	36.0	16.7	68.2	48.7	37.6	90.3
124F	6.6	36.9	16.7	64.6	38.9	38.1	91.7
199F	7.0	36.9	16.6	64.4	41.5	38.1	91.5
L.S.S.	9.9	42.9	17.8	51.3	38.1	39.0	99.7
Sind Sudhar	7.9	39.1	17.2	53.8	37.8	38.9	95.2
Mean	7.6	38.4	17.0	60.4	41.1	38.3	93.7
SOUTH-WEST PUNJAB							
M.4	13.0	45.0	22.8	72.0	31.4	45.8	113.6
124F	10.2	39.0	21.5	57.5	23.7	45.7	106.2
199F	13.3	45.7	22.3	64.4	33.8	48.4	116.4
L.S.S.	28.4	80.0	25.5	72.0	34.8	57.0	162.5
Sind Sudhar	27.2	78.2	26.5	72.5	39.1	54.3	159.0
Mean	18.6	57.6	23.7	67.6	32.5	50.2	131.5

The difference found in the time for the formation of the first fruiting branch in the same varieties grown in the two tracts cannot be attributed to the differences in the maximum temperatures prevailing in the two tracts as the temperatures were equally high in both the tracts when the first fruiting branch was produced. The minimum temperature on the other hand when the first buds were produced in the two tracts was found to be 82° F. and it was possible that this was the critical minimum temperature at which the initiation of buds became possible.

TABLE 12. DIFFERENT PHYSIOLOGICAL CHARACTERS OF THE SAME FIVE VARIETIES UNDER DIFFERENT SOWING DATES (mean of five varieties)

Sowing date	First fruiting node	Number of days after sowing for first bud to appear	Square period	Setting percentage of buds in- to flowers	Setting percentage of flowers into bolls	Boll period	Number of days after sowing for first open boll
SOUTH SIND							
d ₁ (15/4)	6.9	40.0	16.0	51.6	38.7	39.7	95.7
d ₂ (30/4)	7.2	37.5	16.9	60.1	38.3	37.6	92.0
d ₃ (15/5)	7.7	37.3	17.1	68.4	43.3	37.6	92.0
d ₄ (30/5)	8.6	38.8	17.9	61.7	44.1	38.4	95.1
Mean	7.6	38.4	17.0	60.4	44.1	38.3	93.7
SOUTH-WEST PUNJAB							
d ₁ (15/5)	18.8	61.4	23.6	71.2	30.9	50.0	135.0
d ₂ (30/5)	20.3	62.2	23.3	72.0	32.2	50.3	135.0
d ₃ (1/6)	19.6	59.6	23.6	69.2	33.0	50.4	133.6
d ₄ (15/6)	15.1	47.2	24.3	58.0	34.1	50.2	131.7
Mean	18.6	57.6	23.7	67.6	32.5	50.2	131.5

The results of the time taken after sowing for the initiation of buds in the crops sown on different dates indicated that in addition to the temperature there must be some internal factors that were governing this process and the temperature alone was not the only contributing factor. The buds did not appear as soon as the temperature dropped in the late sown crops. The buds appeared after 38 days in Sind for the crops sown even on the 30th May as they appeared in the crops sown on the 30th April. In the Punjab, though the period of bud initiation was reduced only in the case of late maturing varieties when they were sown late, that was not the case with the early varieties. Thus by sowing late, though the interval between the sowing date and fall in temperature was reduced, the bud formation started only after a certain lapse of time. Thus the play of some internal factor or factors is indicated.

The effect of climatic conditions on the development of buds into flowers was visible in the results obtained. The development of buds into flowers proceeded at a quicker rate in Sind than in the Punjab. There was a difference of six days in the mean square period between the two tracts. The square period also remained unaffected by the sowing time of the crop in both the tracts. In the late varieties the square period was longer by one day in Sind and three days in the Punjab than the square period of the early varieties.

The effect of the differences in the climatic conditions in the two tracts was also noticeable in the flowering curves. The flowering set in at an earlier date after sowing in Sind than in the Punjab as a result of early drop in temperature. The flowering was also gradual in Sind while it occurred in a flush in the Punjab. The period for flower formation lasted for nearly four months beginning with the month of June and ending in September in Sind,

while it was of two and a half months duration in the Punjab (Figs. 2, a and b). As the total number of flowers produced per plant was nearly equal at both the centres, the rate of flower production reached a higher level during the peak period in the Punjab than in Sind.

Though there was much marked difference in the initiation and completion of the flowering phase between the early and late varieties in Sind, the early and late maturing varieties in the Punjab were characterised by an early and late initiation of the flowering phase (Figs. 2, a and b). Thus the external distinction between the early and late varieties became marked in the Punjab while it was not so in Sind. The climatic conditions in the Punjab were such that small differences in the earliness and lateness became readily noticeable by the appearance of the first flower.

The results of investigations pointed to the conclusion that those varieties became early which were able to produce their fruiting branches at higher temperatures and when the day was long while the late varieties were those which could develop their fruiting branches only when the temperature dropped and the day length shortened. In Sind these differences in time of development of fruiting branches between early and late varieties became marked as the day length shortened and the temperatures dropped as soon as the internal factors became favourable for bud development, while in the Punjab it took longer time for the onset of favourable external conditions even though internally the plants may have reached the stage for the development of the fruiting branches much earlier than the time of their development.

The percentage of flowers that developed into bolls was higher in Sind than in the Punjab. This may be due to a slow rate of flowering and a longer duration of the flowering phase in Sind.

As in the case of the square period, the boll period in Sind was shorter than in the Punjab. The flowers developed into the open bolls in 36 days in Sind while the same process was completed in 50 days in the Punjab. Thus maturation occurred at a more rapid rate in Sind than in the Punjab. There was probably an effect of night temperatures which were consistently higher in Sind during the latter part of the fruiting period.

On account of the early initiation of the fruiting branches and a shorter square period as well as boll period the crop matured comparatively earlier under Sind conditions than in the Punjab. It took on an average nearly 93 days after sowing for the first open boll to appear in Sind while 131 days elapsed after sowing before the first open boll developed in the Punjab. This difference was still greater when the late maturing varieties were considered. Variety L.S.S. matured in 100 days in Sind while it took 162 days in the Punjab.

The more rapid development of the American cotton plant in Sind may be due to more rapid rate of assimilation in the cotton plant growing there. The net assimilation rate of the American cotton was found to be higher in Sind than in the Punjab and this made possible the shortening of the bud

AVERAGE NUMBER OF FLOWERS PER PLANT (AMERICANS)
(4 DAY TOTALS)

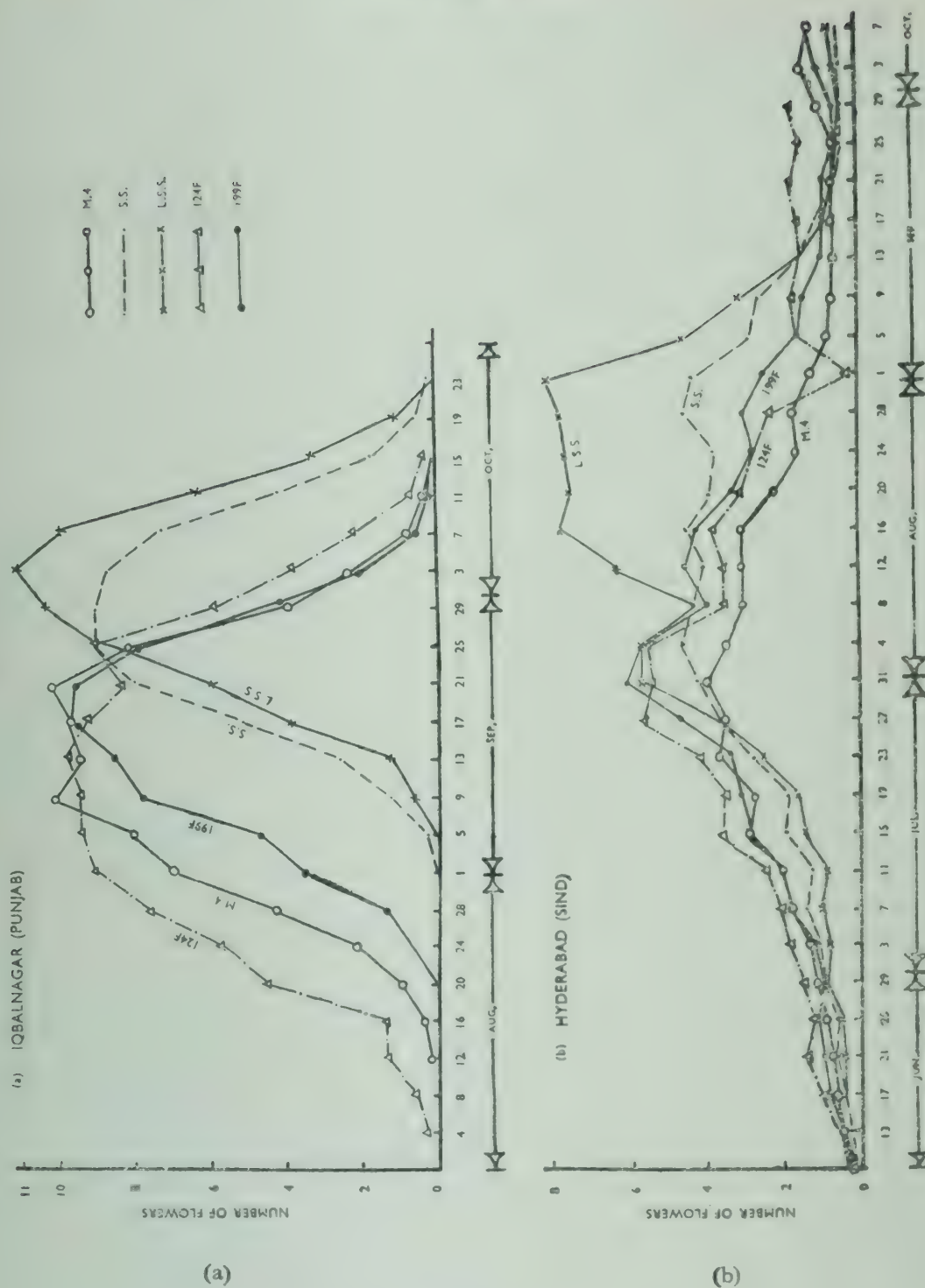


Fig. 2. Flowering Curves for American Cottons in the Punjab and Sind

initiation period, the square period and the boll period in the former tract by making rapidly available the assimilatory products for the requirements of the reproductive phase (Fig. 4). This effect was noticeable on the relative growth rate of the plant in Sind which was very high during the reproductive phase in Sind as compared with the relative growth rate in the Punjab (Fig. 3).

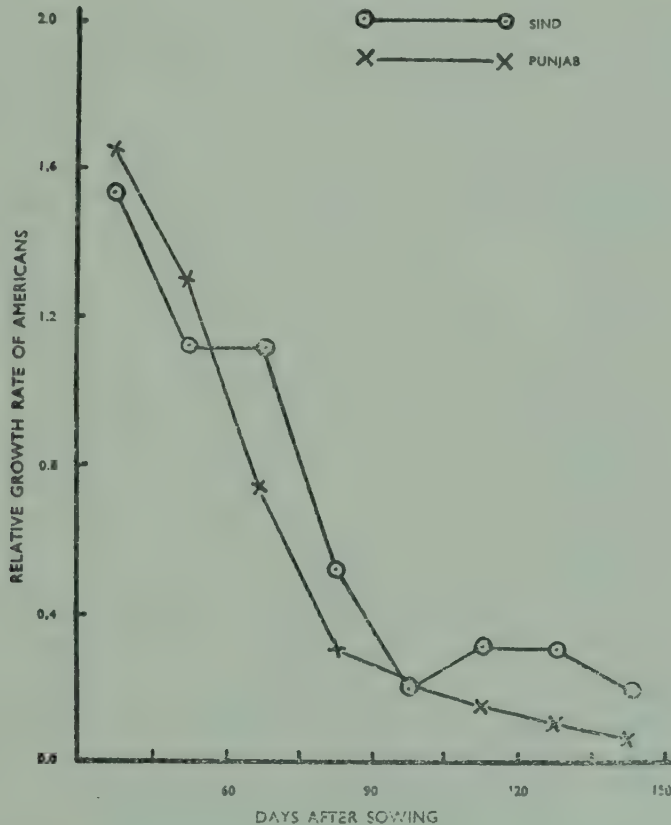


Fig. 3. Relative Growth Rate of American Cotton Plants in the Punjab and Sind

Thus the climatic conditions in Sind were such that they hastened the development and the maturation of the crop. It was difficult to say precisely which were the contributing climatic factors but temperature was surely one of them. Early drop in temperature and higher night temperatures during the fruiting period made for the early initiation and rapid completion of the reproductive phase. It was also possible that the differences in the relative day and night lengths in the two tracts during the season may be playing a part in the early initiation and completion of the reproductive phase. No particular difference between the yields of Sind-Americans grown in the Punjab and of the Punjab-American varieties grown in Sind was, however, noticeable.

COTTON IN INDIA

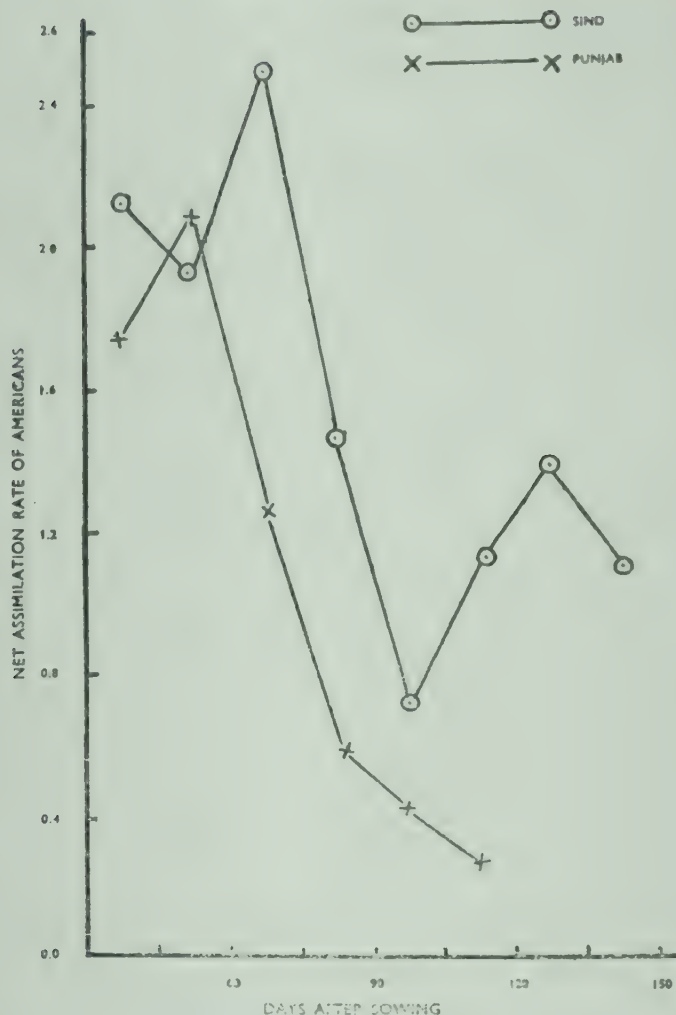


Fig. 4. Net Assimilation Rate of American Cotton Plants in the Punjab and Sind

PHYSIOLOGICAL CHEMISTRY

MINERAL COMPOSITION OF COTTON PLANT

The mineral composition of the cotton plant has been determined by research workers in some other countries (Hutchinson and Patterson, 1892; Fraps, 1919; McHargue, 1926). White (1914, 1915) found that maximum amount of nitrogen, potash and phosphorus was absorbed by the plant at the flowering stage. Similar findings have also been reported by Kudrin (1929); Holley, Pickett and Dulin (1931); Armstrong and Albert (1931); Murphy (1936).

The mineral composition of 4F American cotton plants at maturity in the Punjab on normal soil under usual spacing of 3' x 1½' is given in Table 13. The results showed that the plant contained large amounts of lime, potash, nitrogen and sulphates while the other minerals were found in smaller quantities.

The number of cotton plants with the spacing adopted was roughly 9,000 per acre. The quantity of each mineral absorbed by an acre of the

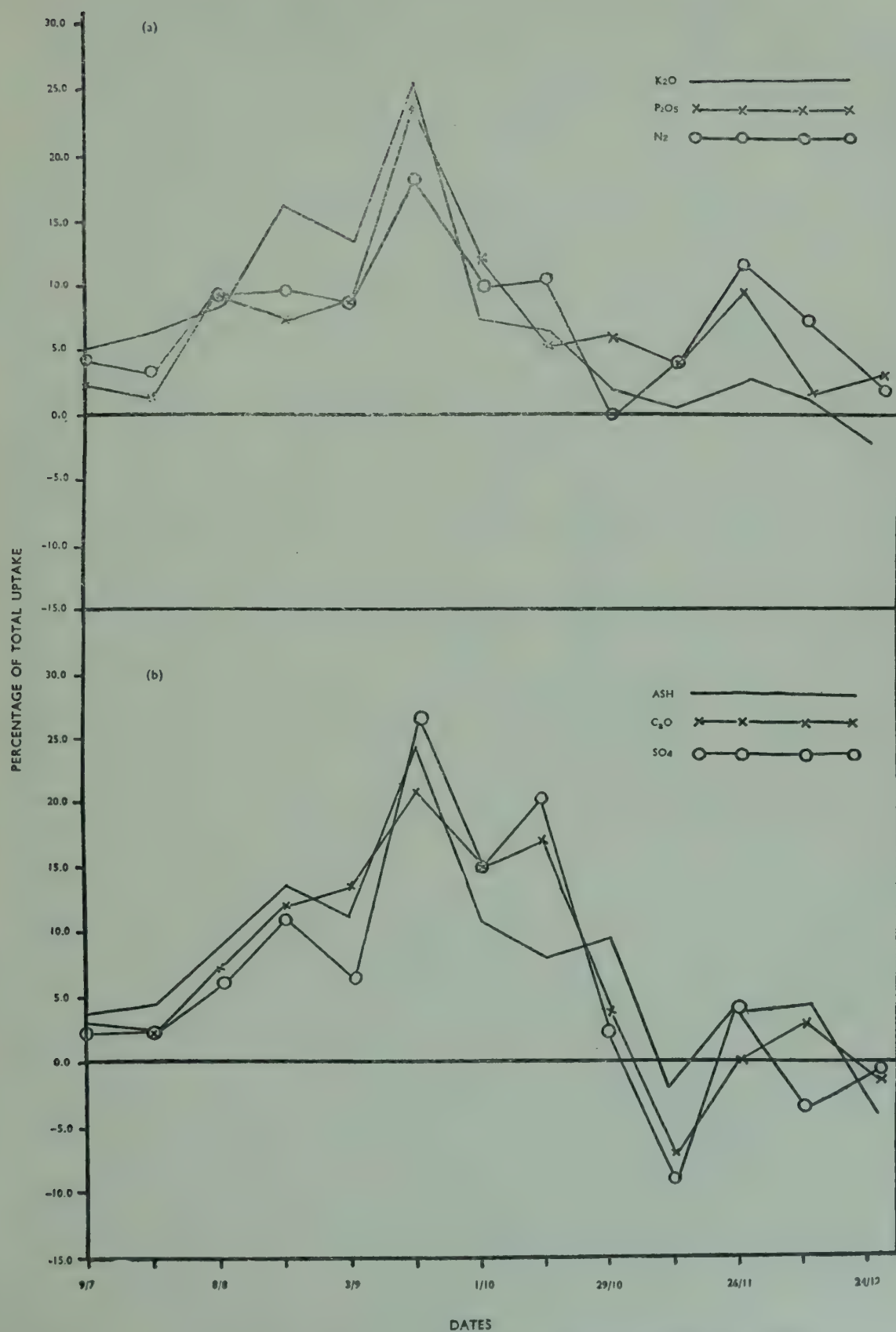


Fig. 5. Percentage of Total Uptake of Various Minerals at Different Stages of Growth

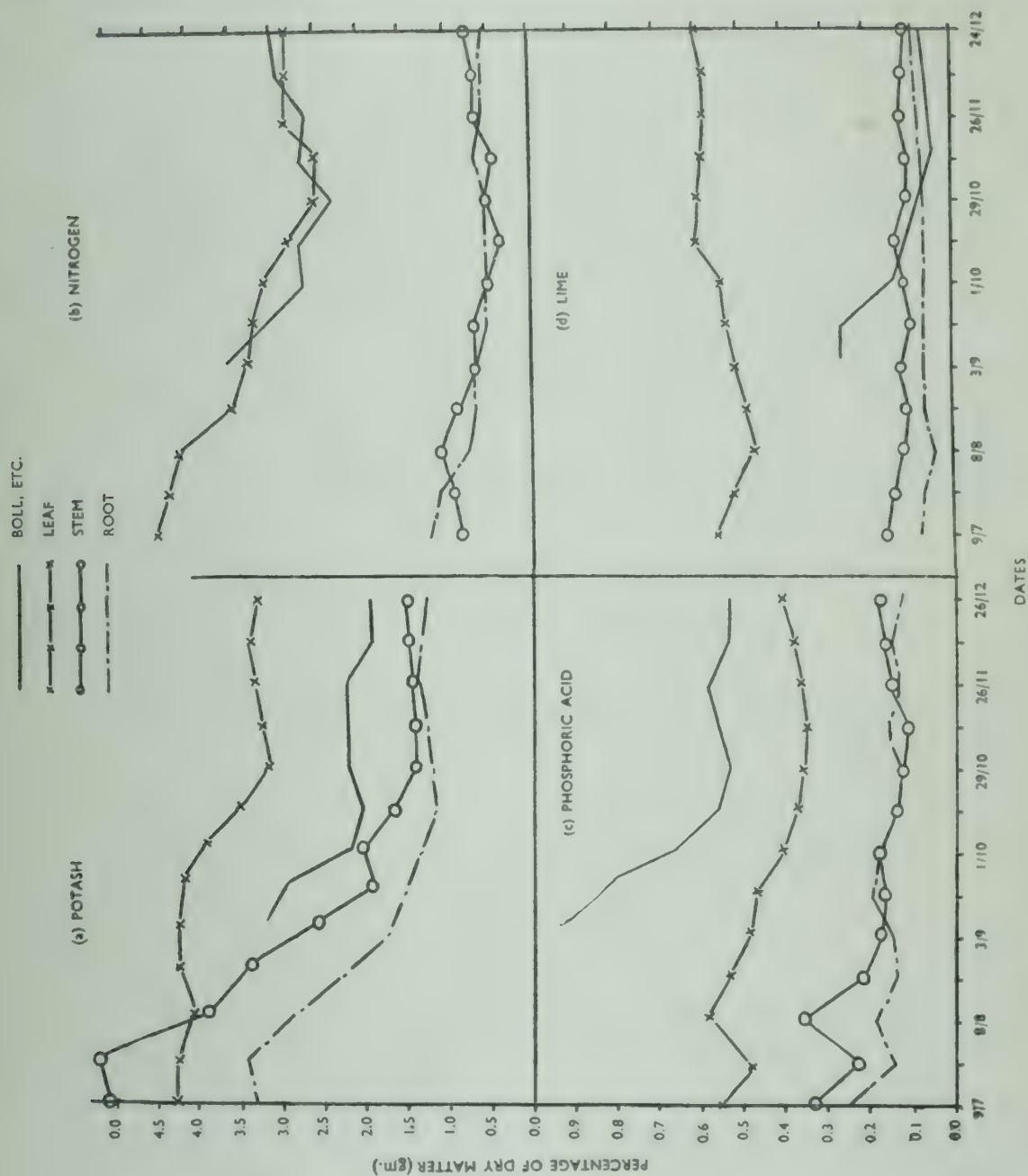


Fig. 6. Percentage of Minerals in Various Plant Parts of 4F Punjab-American Cotton

TABLE 13. MINERAL COMPOSITION OF 4F AMERICAN COTTON PLANTS

Dry weight	Silica free ash	Nitrogen	Potash	Lime	Magnesia	Aluminium + Iron	Phosphoric acid	Sulphates	Chlorides
<i>Gram per Plant</i>									
864.7	69.47	14.52	17.84	19.37	3.79	0.49	3.02	12.95	2.73
<i>Gram per 100 gm. of the Whole Plant</i>									
100	8.04	1.68	2.07	2.24	0.44	0.06	0.35	1.50	0.32

TABLE 14. QUANTITY OF MINERALS ABSORBED PER ACRE

Nitrogen	Potash	Lime	Magnesia	Aluminium + Iron	Phosphoric acid	Sulphates	Chlorides
288	353	384	75	10	60	256	54
<i>Quantity of Minerals Lost from the Soil per Acre</i>							
177	190	90	42	3	40	66	32

American crop sown early in May could thus be calculated and is given in Table 14.

A part of the minerals absorbed was returned to the soil by the roots and the shed leaves which remained in the soil. Therefore, the actual loss of these minerals from the soil was greatly reduced as the leaves contained the largest quantities. Thus, in a field of average fertility there was a loss of 190 lb. of potash, 177 lb. of nitrogen, 90 lb. of lime, 66 lb. of sulphate and 40 lb. of phosphoric acid, every time an acre of the crop was grown in a field, assuming the dry weight of each plant to be 864 gm. The leaves were found to contain maximum concentrations of lime, sulphate and potash when the crop matured.

The mineral composition of the roots, stems, leaves, flowers and bolls was determined at fortnightly intervals to obtain an idea of the uptake at different stages of growth. It was found that the maximum increase in the uptake of each mineral occurred by the middle of September (Figs. 5a and b). This was the stage when the maximum percentage increase in the dry matter of the plant also occurred (Fig. 1).

A study of the concentration of minerals in the different parts of the plant revealed that the concentration of nitrogen and phosphorus decreased in the leaves as the bolls matured while they remained almost constant in the stems and roots (Fig. 6). In the case of potash a decline in the concentration occurred in the roots and stems along with the leaves when fruits developed. Thus the first two elements travelled from the leaves to the bolls, while potash travelled from all the vegetative organs to the fruiting parts. The concentrations of lime and sulphates in the leaves remained unchanged throughout the whole period indicating that there was a continuous absorp-

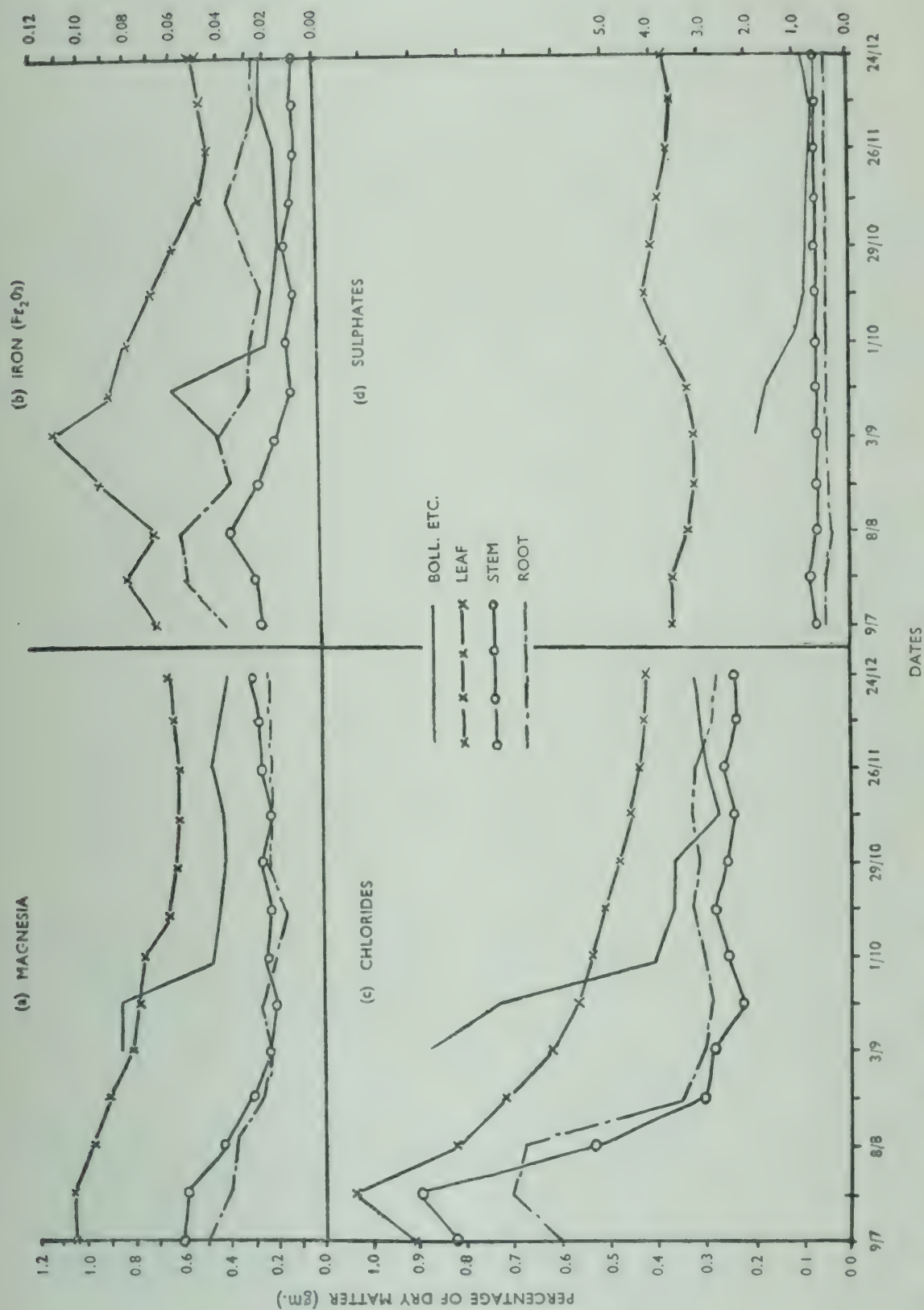


Fig. 7. Percentage of Mineral Salts in Different Parts of 4F Punjab-American Cotton Plant

tion of these minerals from the soil, and the requirements of the bolls were met either directly or *via* the leaves from the soil (Fig. 7). There was also a small decrease in the concentration of magnesia in the leaves up till October after which it remained unchanged. There was an increase in the concentration of iron in all the vegetative parts in the early stages of growth after which there was a fall in the leaves but not in the stem and roots. The concentrations of chlorides declined in the early stages of development in all parts of the plant. Thus most of the minerals except lime and sulphates got depleted from the leaves at the fruiting stage.

A study of the percentage distribution of each of these minerals in the different organs of the plant at different stages of growth also supported the above conclusion that the leaves got depleted of most of their ash constituents and nitrogen when the bolls began to develop. Nitrogen, phosphorus, magnesia, chlorides and iron decreased in leaves while potash decreased in all the vegetative parts. The percentage distribution of lime and sulphates in the leaves remained constant at all stages of growth. For further detailed information on the mineral uptake of cotton plant in the Punjab a reference to the published paper by Dastur and Ahad (1941) may be made.

The concentration of nitrogen, phosphoric acid and up to a certain stage only of lime decreased, while the concentration of potash increased in the carpels as the bolls matured (Table 15).

TABLE 15. PERCENTAGE OF DIFFERENT MINERALS IN DIFFERENT PARTS OF BOLLS AT DIFFERENT STAGES OF DEVELOPMENT

	Age of bolls in days							
	7	14	21	28	35	42	49	56
<i>Percentage of Nitrogen</i>								
Carpels	2.95	1.67	1.40	1.35	1.30	1.27	1.05	0.70
Seeds	3.1	2.76	2.35	2.8	3.1	3.5	3.45	3.48
Lint	1.4	1.15	0.95	0.65	0.55	0.40	0.20	0.15
<i>Percentage of Potash</i>								
Carpels	1.95	1.85	1.75	1.90	2.40	3.15	3.70	4.30
Seeds	2.7	1.95	1.50	1.45	1.30	1.13	1.10	1.15
Lint	3.15	2.40	1.95	1.60	1.30	1.10	0.95	0.60
<i>Percentage of Phosphoric Acid</i>								
Carpels	0.61	0.50	0.35	0.32	0.31	0.24	0.22	0.21
Seeds	1.15	1.0	0.75	0.90	1.15	1.21	1.21	1.22
Lint	—	0.94	0.64	0.41	0.25	0.14	0.10	0.05
<i>Percentage of Lime</i>								
Carpels	2.20	1.33	1.08	0.97	0.95	1.09	1.20	1.47
Seeds	0.95	0.40	0.18	0.24	0.30	0.32	0.31	0.31
Lint	—	0.54	0.39	0.27	0.21	0.20	0.20	0.20

The concentration of nitrogen, phosphoric acid and lime showed a fall in the seeds during the first three weeks of development after which an increase

in their contents was found to occur. Potash on the other hand showed a continuous decline in the seeds.

The concentrations of all the four minerals decreased in the lint as it matured.

A study of the different forms of nitrogen in the carpels and seeds at weekly stages of growth revealed that total nitrogen and protein nitrogen declined in the carpels but they increased in the seeds after the third week of development.

The soluble nitrogen in the carpels on the other hand began to decrease from the fifth week while a continuous decline in the soluble nitrogen in the seeds occurred from the first week up to the last week of development.

The diamino nitrogen in the seeds of normal bolls was higher in the last four weeks though the total soluble nitrogen (which included diamino nitrogen) was lower in the seeds during the same period. The soluble nitrogen in the seeds, therefore, consisted mainly of diamino nitrogen which was being converted into proteins. It was, therefore, clear that primary synthesis of proteins occurred in the carpels. It was again converted into soluble forms of nitrogen in the seeds when they were again converted into proteins.

Caskey and Gallup (1931) have already shown that the oil content increases and sugar decreases in all parts of the boll as development proceeds. The period of maximum oil formation was found to lie between 21st and 30th day of boll development. Similar relationship between oil and sugar contents had been found by Gerber (1897) in the case of walnut and almond, by Ivanow (1911-12) in the case of flax and rape seeds, by Rushkovski (1930) in the case of sunflower seeds, by Eyre (1931) and Johnson (1932) in the case of flax, and by Sahasrabuddhe and Kale (1933) in the case of niger seed. Reaves and Beasley (1935), who studied the development of the cotton embryo, found that sugars were present from the very beginning of embryonic development while oil appeared from the third week.

The results of oil content and the different constants of oil in 4F Punjab-American cotton seeds indicated that the ether extract of the seeds in the first three weeks of development consisted of a waxy substance of a high melting point fluctuating between 52° to 55° C. The real oil formation started from the fourth week of boll development. The oil formation continued to increase up to the eighth week, i.e., till the bolls opened.

The melting point of the ether extract was gradually lowered as the seeds developed till it reached a value of 2° to 3° C. at maturity. There was an increase in the saponification and iodine values of ether extracts as the seeds matured indicating that the fatty acids of low molecular weights and the unsaturated fatty acids in the oil increased as the seeds developed. The acid value of the extract was found to decrease as the seeds developed indicating a decrease in free fatty acids.

The most noticeable feature was the fall in the carbohydrates and a rise in the oil content as the seeds matured. The reducing sugars and starch were present in larger amounts than disaccharides which were present only in very small amounts.

The carbohydrate analysis of the carpels showed that the reducing sugars were present in largest amounts. They showed a rise in the first two weeks after which they declined rapidly. The starch and disaccharides showed a decline at a later stage.

The results described above definitely indicated that oil was formed from carbohydrates. The reducing sugars appeared to be the main translocatory form of carbohydrate utilised in the formation of oil in the seeds as this kind of sugar declined both in the seeds and carpels as development proceeded. The starch and disaccharides found in the carpels and seeds may be regarded as temporary storage products resynthesised from the reducing sugars. These higher forms of carbohydrates appeared to be reconverted into reducing sugars as the latter were being utilised in the synthesis of protein and oil.

The carbohydrate analysis of the lint showed that the reducing sugars were present in largest amounts in the early stages of development. Fifty per cent. of dry weight of lint consisted of reducing sugars in the first week of lint development. Disaccharides were found to be present in minute quantities. The reducing sugars declined as the lint matured until they were almost absent in the fully mature fibers. Similar decrease in the reducing sugars in the lint as it matured was found by Jack and Forest (1940).

The progressive decline in the reducing sugars was accompanied by an increase in the cellulose content of the lint. Thus it was evident that cellulose was formed from the reducing sugars. This was not improbable as the cellulose molecule was made up of a number of dehydrated glucose molecules.

The analysis of cellulose of lint revealed that it was mainly composed of alpha-cellulose while beta-cellulose and gamma-cellulose were present in very small amounts.

CARBOHYDRATE AND NITROGEN METABOLISM

A detailed study of carbohydrate contents of the different parts of the cotton plant was first made by Mason and Maskell (1928-30) in Trinidad (B.W.I.). Their main object was to study the transport of carbohydrates within the plant body, the form in which they were transported, and the channels in the plant body through which the transport took place. They considered that sucrose was the main carbohydrate which was transported and the sieve tubes of the bark were the main paths of conduction.

The first attempt to study the periodic changes in the concentrations of carbohydrate fractions of the cotton plant was made by Ergle (1936) who found a fall in the total sugars from the seedling stage to square formation stage with a very sharp increase during the bolling stage. These studies were

again continued by Ergle, Hessler and Adams (1938) and they also confirmed Ergle's previous finding of a decrease in the concentration at the square formation stage and a sharp rise at the fruiting stage.

A further contribution to our knowledge of carbohydrate concentrations in the cotton plant was made indirectly by Eaton and Joham (1944) in their efforts to determine the causes for a decline in the mineral uptake by the cotton plants when they reached the bolling stage. They concluded from their results that a reduced movement of carbohydrates to the roots at that stage was causing a decline in the mineral uptake as sugars supplied the respiratory material from which energy was derived for utilization in the mineral uptake. The reduced movement of sugars to the roots was a result of the flow of the carbohydrates to the developing bolls.

It had long been believed that carbohydrate supply was a main factor that limited the boll formation. The bolls retained by the plant was a function of the number it could nourish. In order to test this finding Eaton and Rigler (1945) undertook to study the effect of nitrogen and light intensity and fruiting on carbohydrate utilization in the cotton plant. They found that carbohydrate concentration was 2.7 times higher under high light intensity (10,000 f.c.) than under low light intensity (1,000 f.c.). Low light intensity was also found to limit the vegetative growth and fruiting and it can, therefore, be concluded that carbohydrate supply in the low light was the limiting factor. But these conclusions were not supported by their results obtained with high light intensity. Though the high light plants set twice as many bolls per 100 gm. of fresh weight, carbohydrate concentrations in the leaves, root and bark were not reduced to the same level as those found in the low light plants. The question was whether high light intensity alone was responsible for better fruitfulness.

Eaton and Rigler (1945) thought the cause for the greater fruitfulness under high light intensity was either the formation of or inhibition by some hormone which would determine the kind of activity, vegetative or reproductive. Thus the question of the relation between fruitfulness and carbohydrate utilisation remained undetermined.

It is clear from the above short review of the work on the carbohydrate concentrations in the cotton plant from different stand points that the cotton plant at maturity contains certain amount of surplus carbohydrates stored up especially in roots and stems. These amounts varied according to the conditions of their growth. There was also a tendency of accumulation of carbohydrates under low or high nitrogen supply (Eaton and Rigler, 1945) and under conditions of drought (Eaton and Ergle, 1947). There appears to be no relation between fruitfulness and carbohydrate supply as a larger number of bolls is found to be produced by those plants which contain larger quantities of carbohydrate at the end of their fruiting activity.

The cotton plant in Malwa Plateau grows under rather unfavourable seasonal conditions as this cotton tract is mainly rainfed. The cotton is sown at the break of the south-west monsoon in the third week of June when the temperatures drop, the hours of sunshine decrease and soil becomes waterlogged during the months of July and August. These conditions are far from ideal from the point of view of vegetative growth. Cloudy weather and low temperatures may be acting as deterrant to the photosynthetic activity of the plant and production of carbohydrates in the leaves may be greatly reduced. During this period it was observed that plant growth was greatly retarded. They begin to grow from the month of September when the bright weather gradually sets in and the temperature rises. The month of October was the period of maximum vegetative activity and it is also the time when the reproductive growth begins. During those months a marked rise in the photosynthetic activity was expected to occur.

The vegetative structure produced by the cotton plant growing in Malwa tract was small when the cotton was sown with rains. Its average height varied from 18 to 24 inches per plant and its dry weight fluctuated between 5 to 15 gm. The average number of bolls produced per plant varied from two to four. This was very small as compared with plants growing under other tracts both rainfed and irrigated. It would, therefore, be interesting to study the carbohydrate metabolism of the cotton plant to determine how far carbohydrate production under conditions of cloudy weather and low temperature limited the vegetative and reproductive growth and whether at the end of the bolling season there were any surplus carbohydrates stored up in the leaves and stems as was found by the previous workers.

It was, therefore, attempted to study the carbohydrate-nitrogen metabolism of the cotton plant by determining reducing sugars, disaccharides, starch, total nitrogen and protein nitrogen. Samples for analysis were taken at fortnightly intervals from a replicated field experiment. The American variety Indore 1 was planted on the 20th June, 1952. Samples were collected from four leaf stages of the cotton plants on the 1st August till the first picking on the 16th December (Dastur and Bhatt, 1956).

The periodic changes in the carbohydrate contents of the leaves, stems and fruiting parts were studied both on the fresh weight as well as the dry weight basis. As the trends in all the different forms of carbohydrates were similar when studied either on the dry weight or the fresh weight basis the results on the residual dry weight basis only are discussed here.

During the early stages there was a small decrease in reducing sugars from about 1.60 to 0.35 per cent. in the leaves (Fig. 8) after which the concentrations of reducing sugars fluctuated within narrow limits. The early fall in the reducing sugars may either be due to their utilisation in respiration or their conversion after translocation into starch in the stem. A small rise in concentration of the reducing sugars was noticeable at the boll

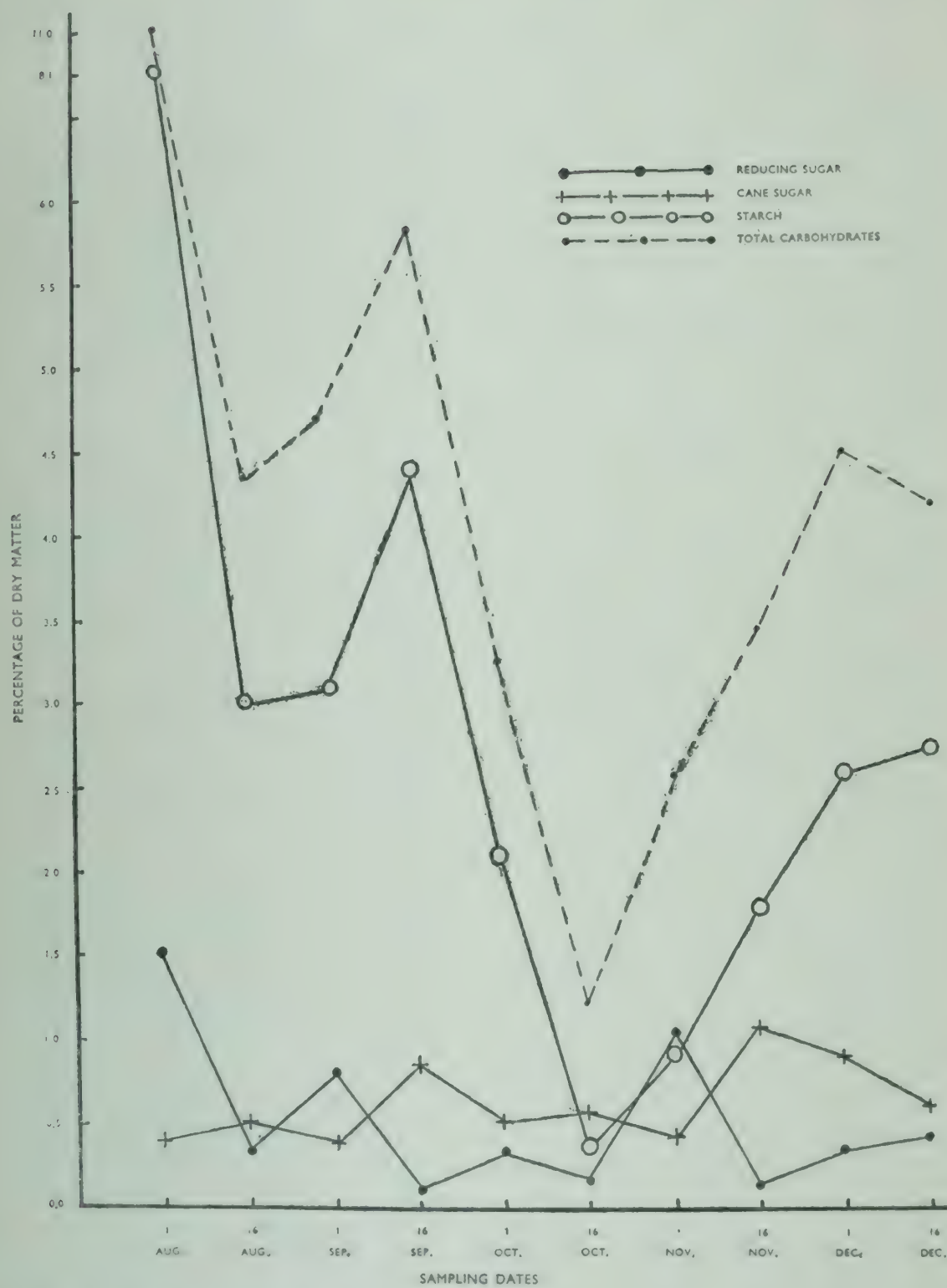


Fig. 8. Carbohydrates in the Leaves

formation stage, i.e., the 1st November, after which a sudden decline occurred. The rise in the reducing sugar curve at the bolling stage may be due to the rapid conversion of starch to sugars for translocation to the developing bolls ; and a decline in concentration later indicated depletion.

The concentration of sucrose fluctuated between 0·40 per cent. in the leaves from the 1st August to the 16th October, the highest concentration during that period being found on the 16th September, i.e., a stage later than the stage at which higher concentration of the reducing sugar in the leaves was found. Similarly, maximum concentration of sucrose occurred at a stage later, i.e., on the 16th November. Thus the maxima of both sugars was reached in November, i.e., at the time when the bolls were maturing, after which the leaves contained very little sugar.

The curve depicting starch concentrations of the leaves at different stages showed a sharp rise and fall quite different from those discussed for hexose and sucrose. It resembled the hexose curve in the early stages. There was a fall in the concentration of starch in the month of August with a rise on the 16th September, i.e., at the same stage when higher concentration of sucrose was found. This rise was followed by a steep fall in October-November. This may be due to its conversion into sugar for translocation to the growing points on account of high vegetative activity and on account of the setting in of the reproduction phase. The leaves contained a fairly large amount of starch unutilised at the boll opening stage as there was a steady rise in starch concentration after the fall on the 16th October.

The remarkable feature of this investigation was a very high concentration of the total carbohydrates found on the 1st August stage. It was nearly 10·5 per cent. of the total dry weight of the leaves. Where did they come from as the month of July was cloudy with low temperatures very unfavourable for photosynthetic activity? It is possible that the main source was the seed which contained large amount of oil which is known to be converted into carbohydrates which are generally utilised for growth. As very little vegetative growth occurred during that period, they may have been stored up in the leaves but later on they appear to be utilised rapidly. The total dry weight of the leaves was also small at that stage.

It was also clear that there was a great accumulation of carbohydrates in the leaves when the plant had nearly reached the stage of senescence. At this stage most of the leaves were old and had reddened. Thus even under climatic conditions prevailing at Indore, much of the carbohydrates appeared to remain unutilised. Most of these carbohydrates were found to be in the form of starch and cane sugar.

The carbohydrate concentrations of the stem including the hypocotyledonary region is given in Figure 9. The reducing sugars fluctuated, after the early fall, within still narrower limits than the reducing sugar in the leaves. A small rise was evident on the 1st November as was the case in the leaf.

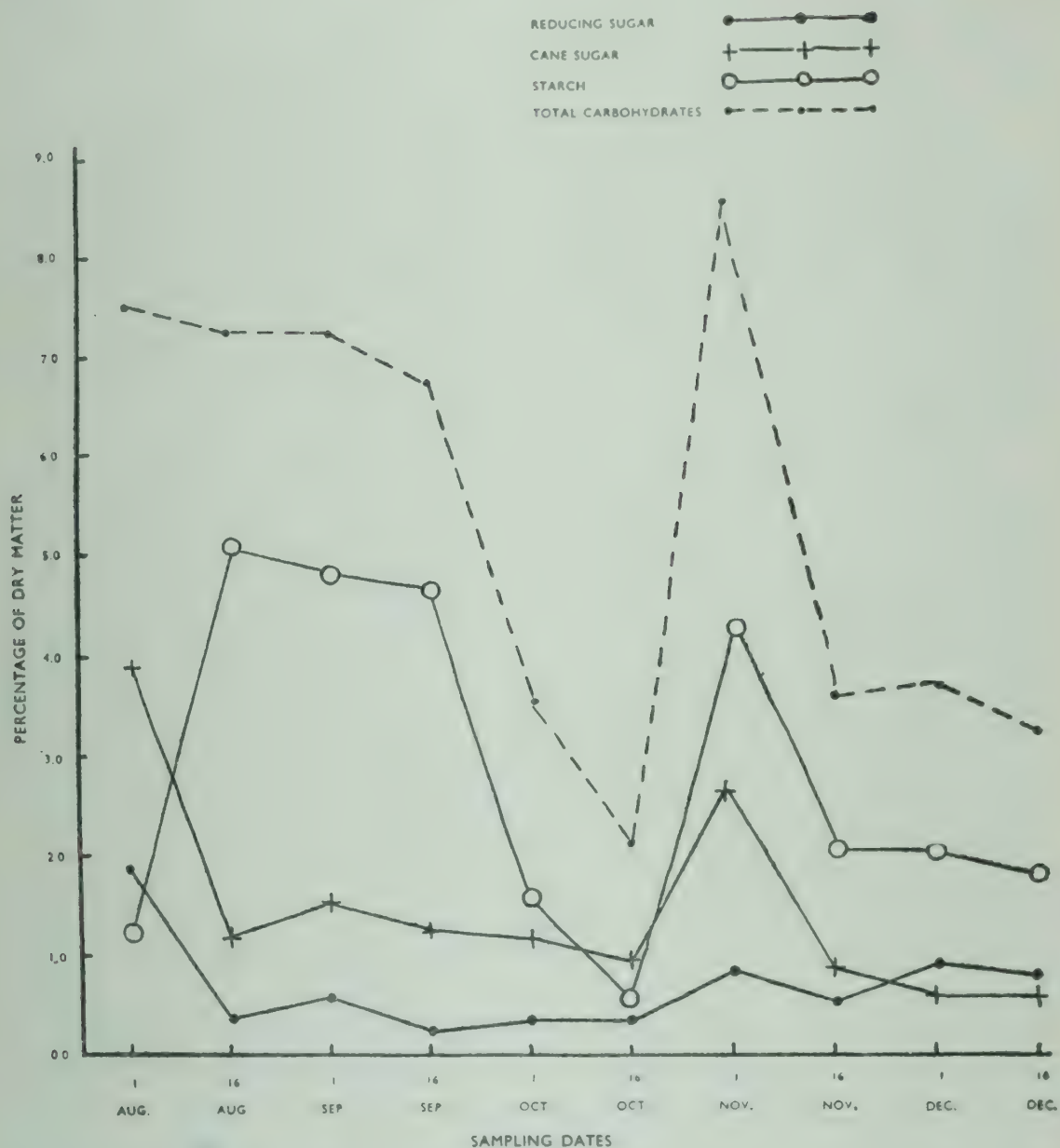


Fig. 9. Carbohydrates in the Stem

The cane sugar curve of the stem also showed similar trends. After an initial fall it remained constant up till November when a small rise was noticeable. It was characterised with a fall from the 1st August up to the 16th October. The cane sugar concentrations in the stem stood always higher than the concentrations of reducing sugars. It appeared that cane sugar being a translocatory form of carbohydrate, did not accumulate in the leaves and was rapidly transported to the stem. It showed that on account of high photosynthetic activity the sugar first accumulated in the stems and later in the leaves. This was followed by a steep fall in sucrose content. It fell from 1.2 to 0.65 per cent. in the leaf and from 2.5 to 0.6 per cent. in

the stem. The utilisation of sugars was very great during the first fortnight of November which appeared to be a period of greatest metabolic activity.

The starch concentration in the stem portions showed a rise in the first fortnight of August. This was the reverse of what was found in the leaf where steep fall in starch content was found. It was likely that transfer of carbohydrate occurred from the leaf for storage in the stem parts. The starch content began decreasing in the stem from that date indicating its utilisation for growth so much so that it was practically nil in the first half of October. It became nil in the leaf a fortnight later, i.e., in the second week of October. Thus simultaneous disappearance of starch both in the leaf and stem was another important finding of carbohydrate metabolism of the plant. There was again a rise in the starch content in the stem in the second half of October with a steep fall in the next fortnight after which it remained constant. No such fall was visible in the leaf where it continued to rise up to the end of the season. The starch content in the leaf was higher than the starch content of the stem at the end of the plant's life cycle.

The total carbohydrates in the stem showed a small decline from August and they fell rapidly in September when the plants began to flower. They were lowest in October. They showed a rise like starch contents and sugar concentration in November after which they declined. There were about three per cent. carbohydrates in the stem at the end of the season, little less than what remained accumulated in the leaf.

The curves for the reducing sugars and cane sugar in the reproductive parts are given in Figure 10. The concentration of the reducing sugars in the reproductive parts was a little higher than what was found in the stem and leaves on the 16th September after which the concentration showed a decrease in the fruiting parts so much so that it was nil on the 1st November when this sugar showed a small rise in the leaves and stem. There was a small rise later which corresponded with a similar rise in the leaf and stem later. At the end of the season very little hexose sugar remained and this must be present in the carpels as reducing sugars were generally not found in the seeds.

The cane sugar curve in the reproductive parts showed similar features as the reducing sugars except for a rise in cane sugar in October after which it fell to the same level as the reducing sugar with a similar rise on the 16th November. The reproductive parts, i.e., carpels plus seeds contained about 0.6 per cent. of cane sugar at the end.

The starch content of the flowering parts also showed a continuous fall till the end of the season reaching the zero level. All the starch which was about 6.1 per cent. appeared to have been utilised in the seed development. All carbohydrates thus travelled to the reproductive parts and were first stored up as starch which was later utilised in the development of bolls. This

COTTON IN INDIA

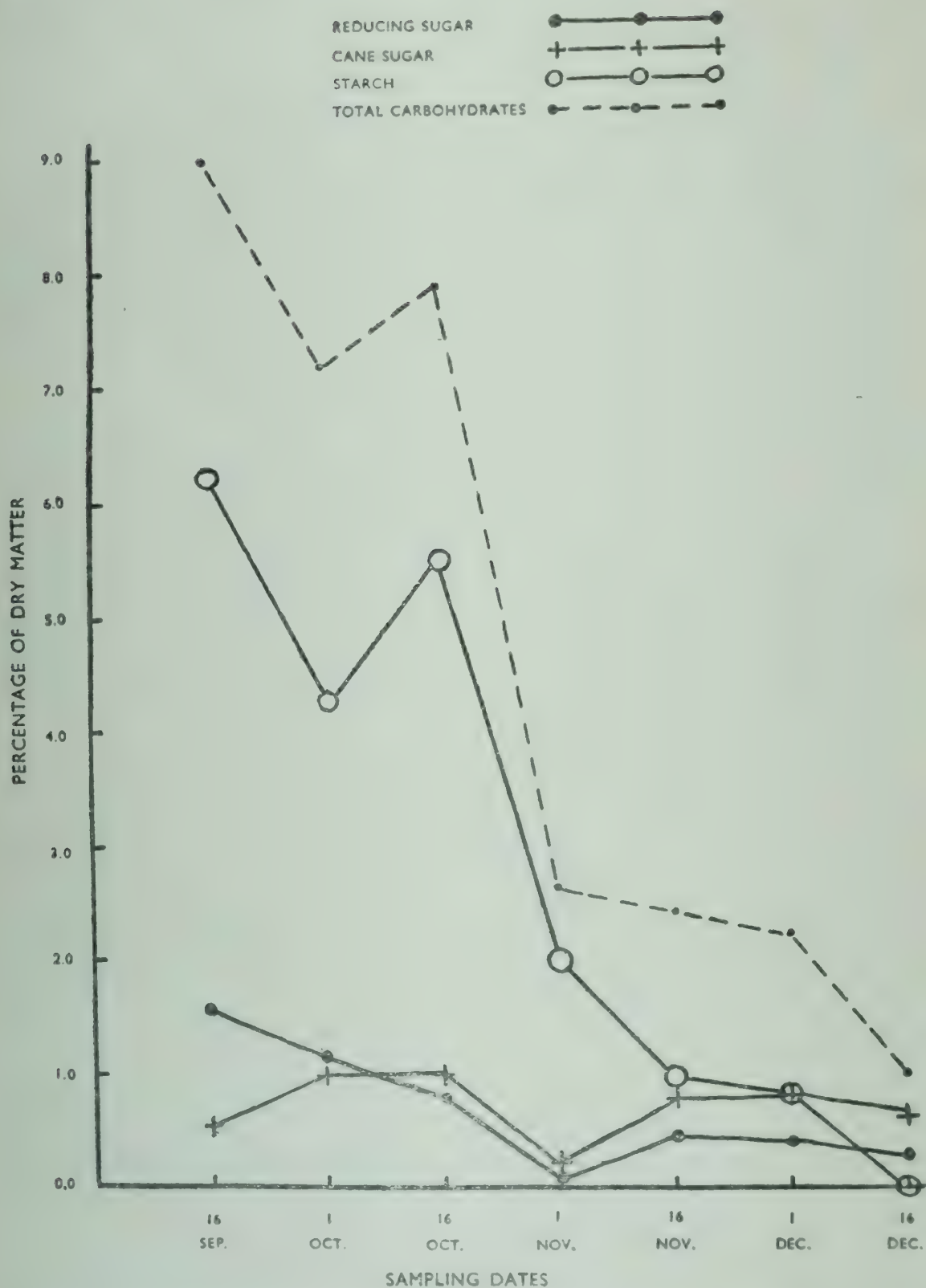


Fig. 10. Carbohydrates in the Flowering Parts

was evident from the total carbohydrate curve given in Figure 10. At the end, there were about one per cent. carbohydrates and these may be present in the carpels or in some bolls that may not have opened when the sample on the 16th December was taken.

As very little growth occurred during the months of July-August, the carbohydrates derived from the oil present in the seed accumulated in the leaf and stem portions of the plant mostly in the form of starch. These were being rapidly utilised when the conditions became favourable for growth. The increase in the carbohydrate contents of the leaves from the 1st September indicated a high photosynthetic activity due to a rise in temperature which went up to 90° F. on account of return of bright weather (Fig. 8). As the input of carbohydrates was not sufficiently large to meet the requirement of the growth, the carbohydrate content of the leaf and stem began to decrease from the 16th September so much so that it became nil on the 1st October and consequently the percentage increase in the dry matter also became nil during the next fortnight. After the 16th October there was a steady accumulation of starch in the leaves. There was about 2.8 per cent. of starch left in the leaves at the end of the season.

The stem parts also contained about 1.8 per cent. of starch at the end of the season. Thus there was enough food material stored up in the stem and leaves at the end of the season. Thus complete utilization of carbohydrates for maturing a larger number of bolls did not occur even under these conditions.

The nitrogen content of the leaves like the hexose and starch content decreased from about three per cent. to two and a half per cent. during the first fortnight of August. It may be due to the fall in absorption of nitrogen from the soil or due to the increase in the dry matter of the leaves. A rise later was indicated, though its concentration did not go beyond three per cent. in any case. The maximum was reached early in October, after which it began to decrease probably on account of its translocation to the developing fruits. The minimum concentration was reached at the end of the maturation period when it fell to 1.75 per cent. in the leaves.

The nitrogen contents of the stems fluctuated within still narrower limits, i.e., from 1.4 per cent. at the beginning in August to about 0.75 per cent. in December at the end.

The nitrogen contents of the reproductive parts declined from the early stage. It dropped from 2.6 per cent. on the 16th September to 1.35 per cent. on the 1st November after which it remained almost constant.

It may be pointed out that the reproductive parts include the buds, flowers, carpels and seeds. These results were, therefore, expected to be different from those given either for carpels or seeds alone by other workers (Dastur and Ahad, 1945). The results of total nitrogen would naturally show a decrease as the sample at each fortnightly stage consists of more and

more fully mature bolls.

The curve for protein nitrogen content resembled the curve for total nitrogen in the leaves except that there was no depression in the protein nitrogen content of the leaves during the first half of August. The protein nitrogen like total nitrogen content later increased, reached a maximum and declined rapidly during the maturation stage.

The protein nitrogen content was found to increase from 1.87 to 2.5 per cent. by the middle of September in the leaves after which it fell to 1.22 per cent. on the 1st December indicating that protein nitrogen was rapidly used up in the formation of reproductive parts.

The protein nitrogen of the stem remained almost constant from the very early stages up to the middle of October after which it showed a rapid fall. There was very little protein nitrogen left in the stem after maturation. These results indicated that proteins were stored up more in the leaves than in the stems and the developing bolls got the proteinaceous food materials mostly from the leaves.

Reproductive parts also similarly indicated that most of the total nitrogen at each stage was in the form of proteins.

A study of the carbohydrate/nitrogen ratio showed a continuous fall in the leaves from the 1st August till the crop came to the flowering phase (Table 16). It dropped to 0.522 on the 16th October after which there was a rise (Dastur and Bhatt, 1956).

TABLE 16. CARBOHYDRATE/NITROGEN RATIOS AT DIFFERENT STAGES OF GROWTH IN COTTON PLANT

Date	Leaf	Stem	Flowering parts	Whole plant
1st August	3.59	5.25	—	3.89
16th August	1.72	7.68	—	2.42
1st September	1.79	7.76	—	2.61
16th September	1.99	4.57	3.38	2.58
1st October	1.08	3.00	3.04	1.55
16th October	0.522	2.04	3.86	2.11
1st November	0.977	7.40	1.82	2.09
16th November	1.48	3.66	1.67	1.84
1st December	2.38	4.56	1.68	2.18
16th December	2.39	4.21	0.70	1.51

This fall and rise in the carbohydrate/nitrogen ratio appeared to be related to the fall and rise in the total carbohydrates of the leaves as the changes in the nitrogen content were of much smaller magnitude during this period. The lowest value of the carbohydrate/nitrogen ratio on the 16th October

in the leaves was due to the fall in the carbohydrate contents on that date and that was accompanied by the lowest increase in the dry matter. It was also a stage when reproductive parts contained largest quantities of carbohydrates. Nearly 60 per cent. of the total carbohydrates present in the plant were found in the reproductive parts, while the leaves contained only 10 per cent. of the total carbohydrates. Thus the low carbohydrate/nitrogen ratio of the leaves appeared to be the result of the rapid utilisation of carbohydrate food for purposes of growth when the seasonal conditions became favourable, while no such fall was noticed in the total nitrogen content.

The later rise in the carbohydrate/nitrogen ratio can be related to the rise in the carbohydrate contents of the leaves. Thus the fall and rise of the carbohydrate/nitrogen ratios was merely an indication on the relative utilisation or accumulation of the carbohydrates in the leaves.

The trends in the carbohydrate/nitrogen ratios of the stem were similar to those of the leaves except that there was a rise in the carbohydrate/nitrogen ratio on the 16th August and the 1st September indicating storage of carbohydrate in the stem. The carbohydrate/nitrogen ratio was as high as 7.76 on the 1st September. It began to fall after that date and was lowest on the 16th October, indicating that the stems like the leaves were depleted of their carbohydrates. There was a remarkable rise in the carbohydrate/nitrogen ratio on the 1st November. It was pointed out earlier that in this fortnight there was expected to be a high photosynthetic activity which produced more quantities of carbohydrates than were utilized for growth. The carbohydrate/nitrogen ratio of the stem also remained very high on account of accumulation of starch in the stems and low nitrogen content of the stem.

The carbohydrate/nitrogen ratio of the reproductive parts was high in the beginning due to high carbohydrate content. It was very high on the 16th October when the carbohydrate/nitrogen ratios of the leaves and stems were lowest. Thus there was a preponderance of the carbohydrates which were utilised in the flower and fruit formation. At the end of the season the carbohydrate/nitrogen ratio became low, as most of the carbohydrates were converted into the structure of the fruiting parts and also oil in the seed.

The carbohydrate/nitrogen ratio of the whole plant at each fortnightly stage was calculated from the total carbohydrate and total nitrogen calculated per plant. The carbohydrate/nitrogen ratio was high on the 1st August and was found to be the lowest on the 1st October after which the value fluctuated within narrow limits.

Too much importance on the relation of the carbohydrate/nitrogen ratio with the setting in of a reproductive phase has been attached by various workers ever since Kraus and Kraybill (1918) first drew attention to this relationship. This relationship was, therefore, studied in the light of the above results. There was a drop in the ratio of the leaves when the plant came into

the flowering activity and it dropped further on the 16th October, when the bolls began to be formed. This drop in the carbohydrate/nitrogen ratio was caused by the utilisation of carbohydrates for growth. The carbohydrate/nitrogen ratio of the leaf was about 1.5 on the 16th September ; but that was not the case with the stem where it was as high as 4.5 because of the transfer of carbohydrates that occur from the leaves *via* the stems. The carbohydrate/nitrogen ratio of the whole plant was 2.58 on the 16th October and 1.55 on the 1st December. Thus it was difficult to say which was the cause and which was the effect. It appears that rapid transfer and more rapid utilisation of the carbohydrates in the formation of the fruiting parts may be the cause of the lowering of the carbohydrate/nitrogen ratio at the time the reproductive phase sets in.

EFFECT OF MICRO-NUTRIENTS

The problem of the role of the trace elements in plant nutrition has assumed great importance during the last 25 years and a great deal of literature has accumulated on the subject. A comprehensive bibliography has been prepared on this subject by the Chilean Nitrate Educational Bureau (1948). The deficiency of any one of the trace elements like boron, copper, zinc, magnesium, molybdenum, etc., has resulted in the development of certain pathological symptoms in different crops. The cotton crop has been no exception as the crinkled leaf of cotton reported from Luisiana (Neal and Lovett, 1938) has now been found to be caused by manganese toxicity on account of relative deficiency of calcium. Similarly the sand drawn disease of cotton in South Carolina (Cooper, 1931) has been attributed to the deficiency of magnesium. Except for these two cases no deficiency disease caused by a deficiency of the micro-nutrients is reported in the case of the cotton crop. Coleman (1945) has recently reported an increasing effect on boll weight and yield of cotton by the use of boron.

A series of field experiments on the effect of the micro-nutrients on cotton were conducted by Dastur and Kanwar Singh (1953) in Malwa tract. The black cotton soils of this tract are known to be alkaline in reaction, the pH of the soil being in the neighbourhood of 8.2 to 8.8. Availability of the micro-nutrients or trace elements as they have been called is known to be low under alkaline conditions. A study of the effect of various trace elements was already undertaken by Dastur in 1936 in the Punjab where the sandy loam soils were also alkaline in reaction but no effect of the applications of any trace elements was visible on the different characters of the American cotton plant in that tract.

An experiment was, therefore, arranged in the cotton season 1947-48 to study the effect of applications of molybdenum, boron, copper, magnesium, iron, manganese, zinc and chromium on the American Upland cotton, Indore 1. The same experiment was repeated in 1948-49 and 1949-50 seasons. The doses

of each element used were kept high varying from 14 lb. of molybdenum to 25 lb. of iron. Copper, manganese, zinc and boron were applied at the rate of 15 to 20 lb. per acre, while chromium was added at the rate of 2 lb. only. Half of the quantity of each element that were added in 1947-48 were applied to the respective plots in the next two seasons. In 1950-51 and 1951-52 cotton seasons, no fresh applications of these elements were made to see if there was any residual effect of the previous applications on the cotton yield in the succeeding seasons. This was important for the study of the economics of such applications.

The crop was under observation throughout the season in all these years and the following important features were noticed : (i) leaves of the plants in all the replicates of molybdenum plots turned turmeric in colour even from the seedling stage. The colour generally disappeared after heavy rains but reappeared later ; (ii) leaves of the plants under manganese, zinc and chromium plots were definitely greener in colour than the leaves of the plants in the remaining plots ; and (iii) crop was definitely early in zinc, manganese and molybdenum plots as compared with the control and other trace elements treated plots.

There was a significant increase in boll number in zinc plots in all the seasons ; in chromium in three seasons out of four and in manganese plots in 1950-51 season only. In 1947-48 season the increase in the boll number in manganese plots was also on the verge of significance. Similarly, boron, copper, magnesium and iron plots showed an increase in boll number per plant but these increases did not reach the level of significance (Table 17).

TABLE 17. BOLLS PER PLANT

Year	Control	Molybdenum	Boron	Copper	Magnesium	Iron	Manganese	Zinc	Chromium	C.D. 5% ±
1947-48	2.20	2.22	2.44	2.35	2.35	2.33	2.59	2.66	2.63	±0.41
1948-49	2.10	2.03	2.48	2.24	2.16	2.14	2.27	2.55	2.54	±0.44
1949-50	1.64	1.71	1.91	1.85	1.82	1.84	1.86	2.06	1.95	±0.36
1950-51	0.98	0.99	1.14	1.10	1.12	1.06	1.47	1.22	1.42	±0.23

There was some effect of micro-nutrients on boll weight but this was not consistent from year to year. The effect on boll weight was significant only in the case of chromium in 1949-50.

When the yields were determined it was found that almost all the trace elements had increased the yield per acre and the statistical analysis of the yield data revealed that the effect on yield was significant in some cases (Table 18).

TABLE 18. YIELD IN MAUNDS PER ACRE

Year	Control	Molybdenum	Boron	Copper	Magnesium	Iron	Manganese	Zinc	Chromium	C.D. 5% ±
1947-48	5.64	5.63	6.09	6.38	6.39	6.47	6.57	6.83	7.12	±0.84
1948-49	6.03	6.31	6.98	6.83	6.53	6.30	6.52	7.08	7.49	±0.92
1949-50	4.84	5.18	5.79	5.61	5.18	5.11	5.64	5.61	5.79	±0.73
1950-51	2.74	3.03	3.09	3.15	3.00	3.12	3.36	3.05	3.21	±0.58

In 1947-48 the application of chromium, zinc and manganese was found to increase the yield significantly while the increases due to boron, copper, magnesium and iron were not significant. In 1948-49 chromium and zinc again gave significant increases in yield while the increase due to manganese did not reach the level of significance. In addition boron gave a significant increase in yield. There was an increase in yield due to molybdenum but was too small to be significant. Increases in yield, though not significant, were also due to copper, magnesium and iron. In 1949-50 the five elements, chromium, zinc, copper, manganese and boron, gave significant increases in yield, while increases due to the remaining elements were small and non-significant. In the fourth year (1950-51), trace elements were not added at all to study their residual effects on yield. Per acre yield in this year was reduced to nearly half as compared to that of the previous seasons. This was partly caused by the delay in sowing on account of late break of the monsoon. There was also a partial failure of late rains. The fall in the general level of the yield may also be due to cotton being grown in the same field for the four consecutive years. This is evident from the level of the yield in 1949-50. On account of this fall in the level of the yield it was probable that the effect of the trace elements on yields in 1950-51 was small and insignificant. It is also possible that the residual effect of those applications was smaller. The effect due to manganese alone was significant in that year while the increases in yield due to chromium and copper were on the verge of significance. Zinc and boron did not give significant increases in yield. In spite of a great fall in the level of yield there was some effect noticeable on yields on account of applications of these micro-nutrients in the previous year.

The percentage increase in yield was highest in the case of chromium. The next best were zinc and manganese. There was about 15 per cent. increase in yield on an average due to copper and boron. The results of 1950-51 did not reveal a marked fall in the percentage increase in yield due to these five elements except in the case of chromium. This element was added in the smallest quantity of 2 lb. per acre and it is possible that the residual effect may be small and may decrease from year to year.

Molybdenum plots showed an increasing effect on yield from 1948 to 1950. There was a small increase in yield due to iron and magnesium but in no year these increases reached the level of significance.

There is a definite evidence that the application of copper, boron, zinc, manganese and chromium increases the cotton yields of American Upland cottons in Malwa tract where the soil conditions are alkaline in reaction. The increases in yield varied from season to season. It also varied from element to element from 10 to 25 per cent. of the normal. The increase in yield was probably caused by an increase in the boll production.

As the cost of these micro-nutrients is high as compared to the increase in yield these applications can only be economical if the effect of one application lasted for three years. Similarly smaller doses of these micro-nutrients were not found to be effective.

As an economic measure cotton seeds were soaked in solutions of different concentrations of these elements for varying periods of time with a view to supply the micro-nutrient requirements of the plant by this method and the consequent effects on yield were studied for three years consecutively. However, none of these treatments showed any effect on growth or yield. It was, therefore, clear that higher doses of these micro-nutrients than used normally for various crops were necessary to produce any effect on yield in such soils with an alkaline reaction.

It may also be pointed out that the cotton crop in this tract does not show any symptoms of deficiency of any micro-nutrients under field conditions. There was also no effect produced on the oxidation reduction potential of the soil by the use of these elements.

EFFECT OF APPLICATION OF PLANT HORMONES

EFFECT ON MORPHOLOGICAL CHARACTERS

It has now been established that those unknown forces which regulate the growth and movement of plants are the chemical substances of organic nature now widely known as auxins or phytohormones. A large number of organic acids have now been synthesised in the laboratory and their effects observed on a variety of plants of economic importance. These physiologically active chemicals may cause cell elongation, resulting in curvatures of stem and epinasty of leaves, proliferations, increasing cell division and induction of adventitious roots, inhibition of buds and regulation of the rate of growth.

The synthetic plant hormones are indole acids, substituted phenoxy and benzoic acids, phenoxy derivatives of lower fatty acids or xylenoxy compounds. Some of these substances are available in the form of commercial products such as saradix, planofix, hortomone, etc.

Numerous workers have observed the changes in morphological and physiological characters of plants due to applications of the plant hormones and a considerable amount of literature has been accumulated. Production of seedless fruits, prevention of preharvest apple drop, root initiation and bud initiation in potatoes can be mentioned as some of the beneficial effects of

the plant hormones. Phenoxy compounds such as 2, 4-D are used as weed-killers in crop fields and it was, therefore, necessary to study their effects on the crop plants before they could be used for weed control. Some of these substances are, however, found to produce beneficial effects on the crop plants when used in very low concentrations varying from one to ten parts per million. A study of the effect of the plant hormones on the morphological characters of the cotton plant was first undertaken by Dastur and Ved Prakash (1954) from 1948. The hormones used were a-indole acetic acid, b-naphthoxy acetic acid, a-indole butyric acid, a-naphthalene acetic acid, 2, 3, 5-tri-iodo-benzoic acid, 2, 4-dichloro-phenoxy acetic acid and coumarin. They used solutions of these substances as spray as well as applied them to the soil. The varieties experimented upon were Indore 1 (*G. hirsutum*) and Malvi 9 (*G. arboreum*). 2, 3, 5-tri-iodo-benzoic acid when either applied as a spray or to the soil made the plants shorter and bushy. There was a decrease in height and internodal length and an increase in node production. These effects were produced on both the varieties but the decrease in height was greater in *desi* variety than in the American variety (Table 19).

TABLE 19. EFFECT OF 2, 3, 5-TRI-iodo-BENZOIC ACID ON MORPHOLOGICAL CHARACTERS OF COTTON PLANT

Treatment concentration (mg. per litre)	Increase in height (cm.)	Increase in internodal length (cm.)	Increase in nodes per plant	Number of flowers per plant	Number of bolls per plant	Boll weight (gm.)	Yield per plant (gm.)
Spray							
<i>Indore I (G. hirsutum)</i>							
Control	12.66	1.19	11.9	5.8	2.5	2.1	5.28
50	11.48	1.20	11.3	8.3**	3.6**	2.0	6.37*
100	10.97*	0.84**	12.2	8.6**	3.9**	1.4	5.30
150	11.86	0.99**	13.0*	7.2**	4.0**	1.8	7.33**
S.E.	±0.87	±0.99	±0.98	±0.75	±0.23	±0.21	±0.62
<i>Malvi 9 (G. arboreum)</i>							
Control	35.8	2.11	5.6	12.6	5.6	1.22	7.85
50	22.0**	1.51**	3.3	10.3	3.3	1.50	5.09
100	20.5**	1.45**	6.4	13.1	6.4	1.23	8.07
150	17.2**	1.08**	4.3*	7.9	4.3	1.61*	7.10
S.E.	±2.4	±0.08	±0.56	±1.29	±0.44	±0.18	±0.67
Soil Application							
<i>Indore I (G. hirsutum)</i>							
Control	19.87	0.49	9.5	14.9	6.8	2.01	13.71
5 mg.	18.50	0.39*	9.6	17.2	7.8	3.08**	22.74*
7.5 mg.	17.26	0.38*	9.7	17.2	5.4	3.10**	17.16*
10 mg.	17.26	0.39*	10.2	15.4	5.0	2.71**	13.69
S.E.	±2.1	±0.02	±1.9	±1.9	±1.1	±0.23	±1.61
<i>Malvi 9 (G. arboreum)</i>							
Control	38.8	1.17	11.2	17.2	11.6	1.21	15.28
5 mg.	51.3*	1.33	13.4	21.2*	11.4	1.68*	18.7**
7.5 mg.	38.4	0.77	13.2	17.4	11.0	1.43	15.18
10 mg.	31.36	0.66	11.8	17.4	9.6	1.43	13.17
S.E.	±3.12	±0.51	±1.5	±1.41	±1.3	±0.12	±1.21

Spraying increased the number of flowers produced per plant in the case of American variety only, while soil application showed no effect. The same conclusion held good for the number of bolls produced per plant. This effect was significant under all concentrations in the American variety while it reached the level of significance in the lower concentration only in *desi* variety (Table 19). Spraying as well as soil application appeared to increase the yield per plant in the American variety.

2, 4-dichloro-phenoxy acetic acid produced more qualitative structural changes in the cotton plant rather than quantitative (Bhatt, 1957).

The most common effect produced by this hormone when either used as spray or added to the soil was the significant increase in the number of monopodial branches in both the varieties in all concentrations. The total number of flowers produced per plant had significantly increased under highest concentration in both the varieties when the plants were sprayed. There was also an increase in the number of flowers produced per plant in the low and medium concentrations but no increase in boll number was registered. There was a decrease in the setting percentage in higher concentrations in the sprayed plants but the yield of seed cotton per plant appeared to be unaffected.

Symptoms exhibited by the leaves varied from slight modification to severe malformations. Some were narrowly lobed while quite a number of them entirely changed their shape and size. The veins assumed more or less parallel positions, each vein ending in a long tapering apex. Microscopic examination of such leaves showed dilation of the mesophyll tissue and less number of chloroplasts in the palisade cells.

In many flowers the bracts had fused and formed a sheath around the developing flowers and bolls (Plate Ia). Quite a number of flowers developed a structure resembling the calyx between the normal calyx and the bracts which may for the sake of convenience be termed the secondary calyx. The petals united forming a tabular gamopetalous corolla unlike the poly-petalous form found in both the cotton species (Plate Ia) (Bhatt, 1957).

Alfa-naphthalene acetic acid was found to increase the setting percentage of the flowers into bolls produced by the plant while the boll weight was definitely influenced in the sprayed plants of the American variety in two seasons, and of *desi* variety in one season only. In one season there was a significant increase in the boll number per plant of *desi* variety when this hormone was either sprayed or added to the soil. Thus it either increased the weight of boll or the boll number and this effect on bolls was reflected on the weight of seed cotton per plant.

Alfa-indolyl-butyric acid did not produce any consistent effect on any morphological characters of the cotton plant except that there was an increase in setting percentage. This hormone like alfa-naphthalene acetic acid is also known to decrease the preharvest drop of fruits. There was also

an indication of a slight increase in yield in the American variety under certain concentrations but no definite statement can be made Table 20.

TABLE 20. EFFECTS OF ALFA-NAPHTHALENE ACETIC ACID ON MORPHOLOGICAL CHARACTERS OF COTTON PLANT

Treatment concentrations (mg. per litre)	Number of flowers per plant	Number of bolls per plant	Setting percentage	Boll weight (gm.)	Yield per plant (gm.)
Soil Application					
<i>Indore 1</i>					
1950-51					
Control	6.6	3.6	54.5	0.93	3.40
10 mg.	5.0*	4.4**	77.7**	1.12	5.10**
20 mg.	4.5*	3.6	64.4	1.30	4.72**
30 mg.	5.3	3.8	71.6*	1.25	4.30*
S.E.	± 0.47	± 0.22	± 7.0	± 0.21	± 0.31
1951-52					
Control	16.6	5.4	31.70	2.22	12.0
10 mg.	14.6	6.6	41.2*	2.52	12.12
20 mg.	16.8	6.4	39.90	2.91*	18.62**
30 mg.	14.4	5.6	41.28*	2.83	13.16
S.E.	± 1.8	± 0.6	± 3.40	± 0.15	± 1.9
<i>Malvi 9</i>					
1950-51					
Control	7.4	3.6	50.0	0.91	3.98
10 mg.	7.0	4.2	60.0*	1.60*	7.25**
20 mg.	6.8	3.8	55.8	1.78*	5.70
30 mg.	6.8	3.8	52.0	1.48	4.08
S.E.	± 0.65	± 0.41	± 3.1	± 0.17	± 0.32
1951-52					
Control	14.4	6.2	43.2	1.67	10.4
10 mg.	13.4	7.8	61.5*	1.59	12.44
20 mg.	16.4	9.8**	58.9*	1.72	15.44
30 mg.	17.0	10.8**	65.9**	1.96	16.32*
S.E.	± 1.4	± 0.9	± 5.9	± 0.23	± 2.31

EFFECT ON CARBOHYDRATE AND NITROGEN METABOLISM

It appeared from the changes produced by the plant hormones on the morphological characters that they influence in some way the carbohydrate and nitrogen metabolism of the plant. Maturation of greater number of bolls by their applications may mean either more effective utilisation of the carbohydrate or an increase in the enzymatic activities through the production of auxins or a higher photosynthetic activity. Dastur and Bhatt (1956) studied the periodic changes in the carbohydrate and nitrogen contents and dry weight in the hormone treated and untreated plants of American Upland cotton, Indore 1 (*G. hirsutum*).

An analysis of different parts of cotton plants sprayed with three chemical hormones, viz., TIBA, NAA and IBA for different carbohydrates revealed

CANE SUGAR IN LEAVES

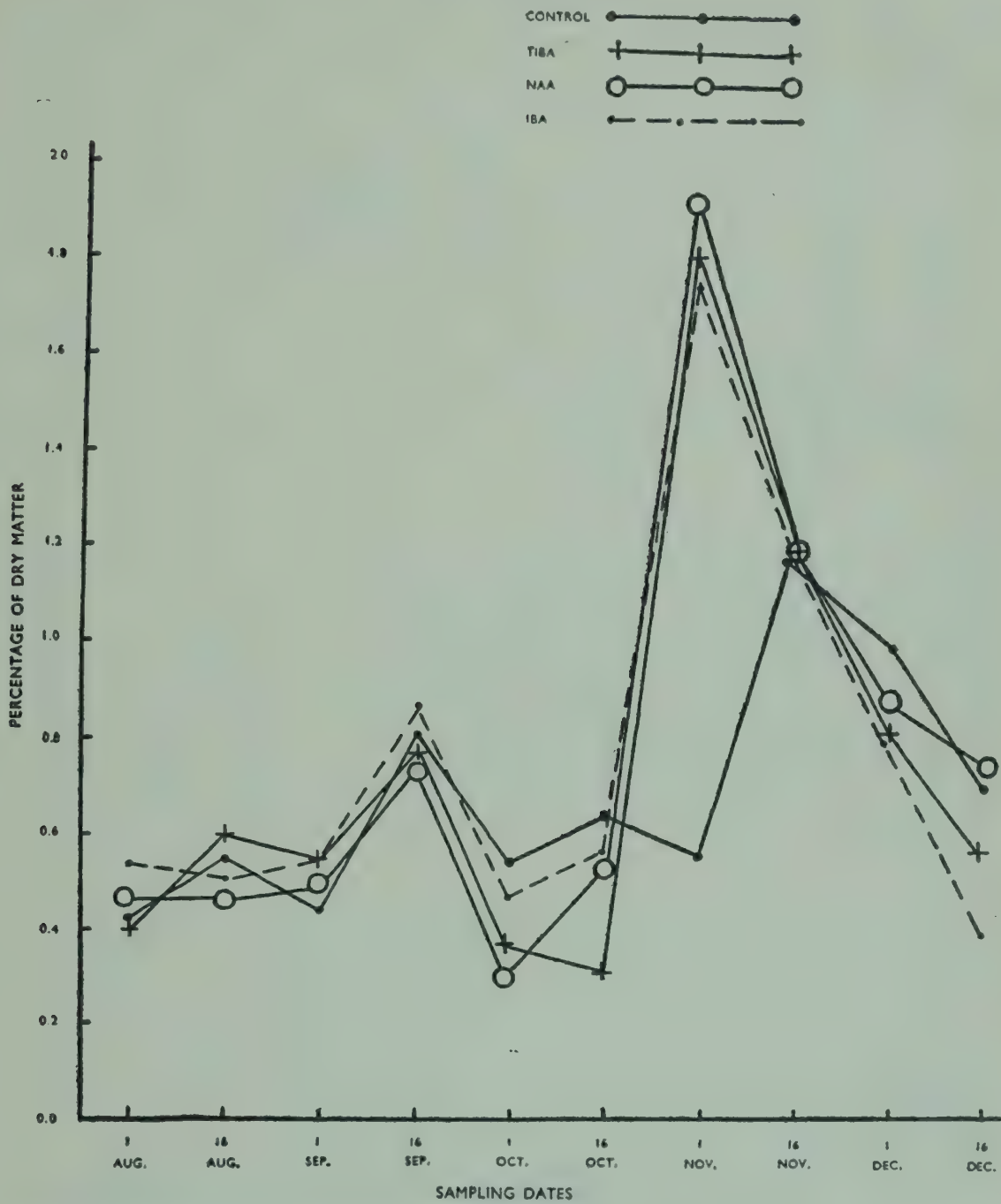


Fig. 11. Cane Sugar in the Leaves

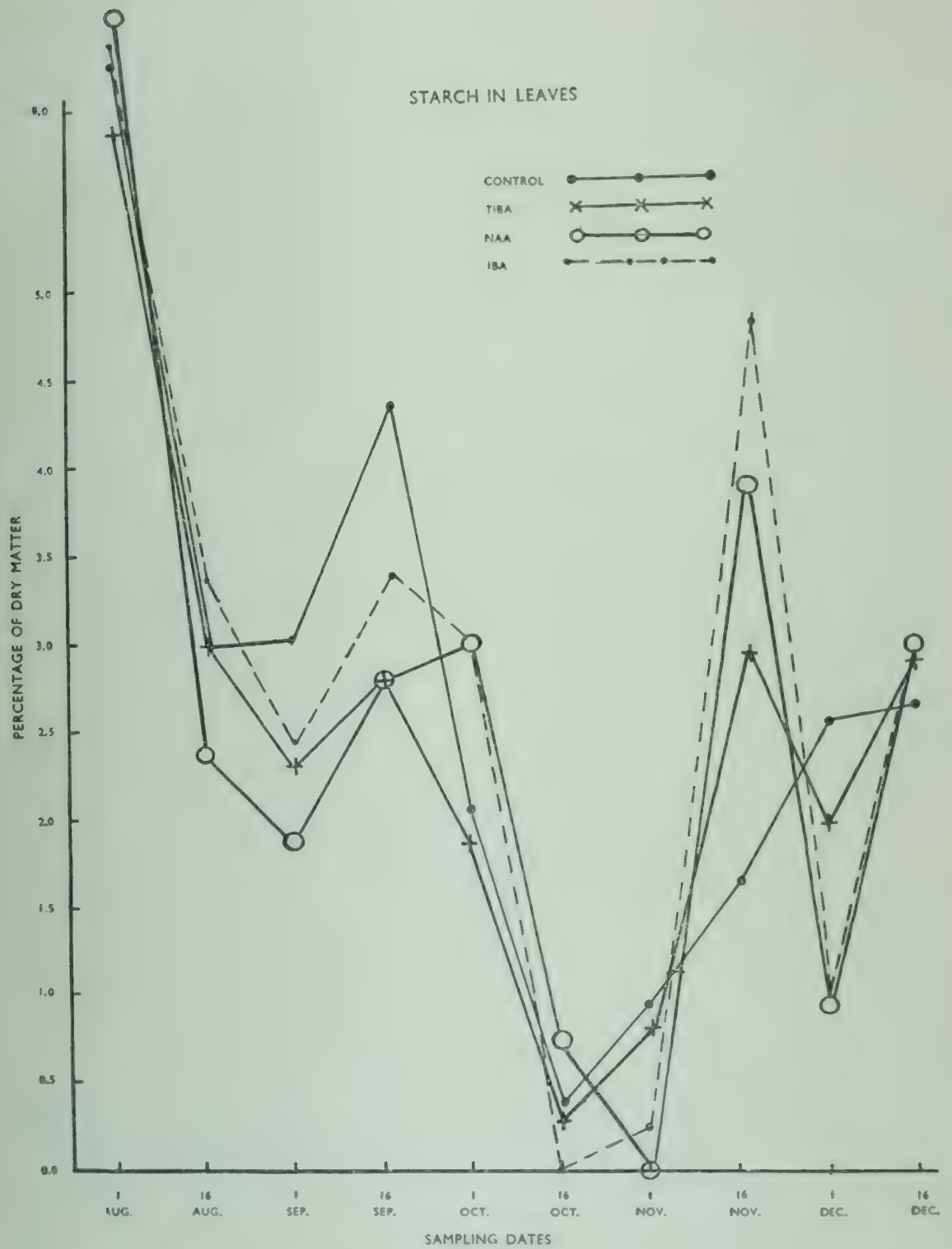


Fig. 12. Starch in the Leaves

that these hormones produced some effect on the carbohydrate production even though they were known to be rapidly utilised in forming cellular structure and in respiration. The leaves of all the three hormone treated plants showed a higher carbohydrate content than the leaves of the control plants at certain stages only indicating a higher photosynthetic activity at that stage. This effect of hormones was evident during the stage of the plants when they displayed maximum metabolic activities, i.e., in October-November, when the plants were in the reproductive stage and when the percentage increase in the dry matter also was found to be the highest.

The concentrations of the reducing sugar and cane sugar in the leaves at different stages under different treatments did not show any marked difference except at one stage, i.e., on the 1st November. The maximum concentration of sugars occurred on the 1st November in both treated and control plants but the concentration of sugars in the hormone treated plants were higher than the concentration of sugars in the leaves of the control plants (Fig. 11).

The same remarks applied to the starch contents of the leaves under different treatments except that the periods for the lowest and the highest starch contents were shifted forward by a fortnight (Fig. 12). On the 16th October and the 1st November starch content was lowest while it was highest on the 16th November. The plants treated with IBA showed highest starch content while it was higher in TIBA and NAA treated plants than in the control. A sharp fall in starch content after the 16th November was another feature of the treated plants different from the control plants where there was a continuous rise in the starch content. At the end of maturity the starch contents of leaves of all the plants tended to be nearly equal (Fig. 12).

It appeared that chemical hormones had produced a marked effect on the photosynthetic activities of leaves during the most active period of the life cycle of the plant on account of their greater accumulation in the leaves.

Similar effects, as in the case of the leaves sprayed with chemical hormones, on the reducing sugars and on cane sugar contents of the stems were also produced. The effect was evident during the fruiting stage, i.e., from the 1st October to the 1st December, when the sugar contents were higher in the hormone treated plants than in the control.

The greater accumulation of starch in the stems of plants treated with chemical hormones, however, did not occur at any stage as was the case with hexoses and sucrose. But this effect was visible at the end of the life cycle when nearly four per cent. of starch remained stored up in the stem of NAA treated plants as compared with 1.8 per cent. in the stems of control plants.

Thus the best evidence of the effect of hormones on the carbohydrate contents of the plants was visible in the leaves when two carbohydrates, viz., cane sugar and starch, were higher in the treated plants. As the leaf was

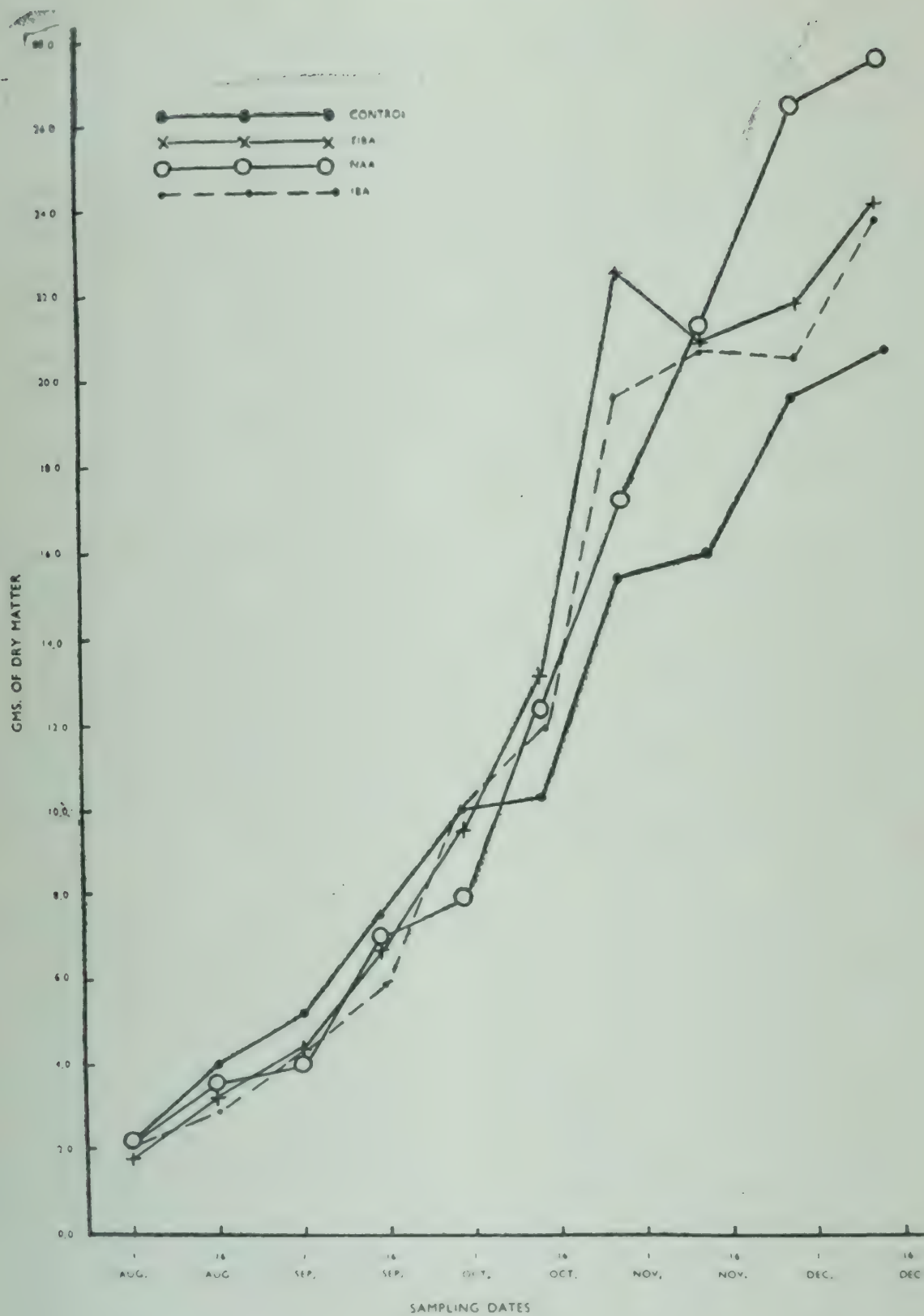


Fig. 13. Total Dry Weight

the chief photosynthetic organ, the effect of the higher photosynthetic activity produced by these treatments was seen in the leaves.

The reducing sugar contents of the reproductive parts of the treated plants were found to be consistently higher at all stages of reproductive activity than the reducing sugar concentrations of the corresponding parts of the control plants. It was clear that more carbohydrate food in the form of hexoses was available for the development of the flowers and bolls when the plants were sprayed with the hormones. The plants treated with IBA showed the highest concentration of reducing sugars.

The values of cane sugar concentrations in the reproductive parts under different treatments did not show any marked differences, while the starch contents appeared to be higher in TIBA treated plants only.

As the hexoses provided the chief building material, their higher concentration at all stages in the treated plants was a remarkable result. It indicated that more carbohydrate food was available for the growth of the reproductive parts in the hormone treated plants. If this was a true effect, there was expected to be an increased reproductive activity in the treated plants than in the control plants. This was actually found to be the case.

Any treatment that increases the photosynthetic activity of the leaves must also effect the growth made by the plants, as the metabolic carbohydrates supply the chief material which builds the plant body. The dry weights of the leaves, stem portions and fruiting parts and the total dry weight per plant of an adequate number of plants were, therefore, recorded at fortnightly intervals, under each treatment (Fig. 13). The dry weight per plant in the control and treated series did not show any marked difference up to the 1st October. Thus the effect of treatment was not visible in the total dry matter produced up to that stage. The effect of hormones became visible when the plants came into the reproductive phase. The dry weight of the treated plants became higher after this date than those of the control plants and remained higher up to the end. This was thus a clear indication of the increased metabolic activity of the plants treated with hormones.

The plants treated with NAA attained the highest dry weight (Fig. 13). It produced 6 gm. more of dry matter per plant than the control plants while the weight per plant in the case of the other two hormones was nearly 23.5 gm. as compared to 20.0 gm. in the case of the control plant. Thus the increased production of dry matter per plant in the hormone treated plants suggested a definite increase in the formation of carbohydrates by photosynthetic activity.

As the total dry weight per plant was the sum of the total dry weight of the leaves, stems and fruiting parts, it was necessary to determine whether the application of hormones affected the growth of the leaves, stems or flowering parts, or any two of those organs or of all the organs.

No effect on the growth of the leaves of any one of the chemical hor-

DRY WEIGHT OF FLOWERING PARTS

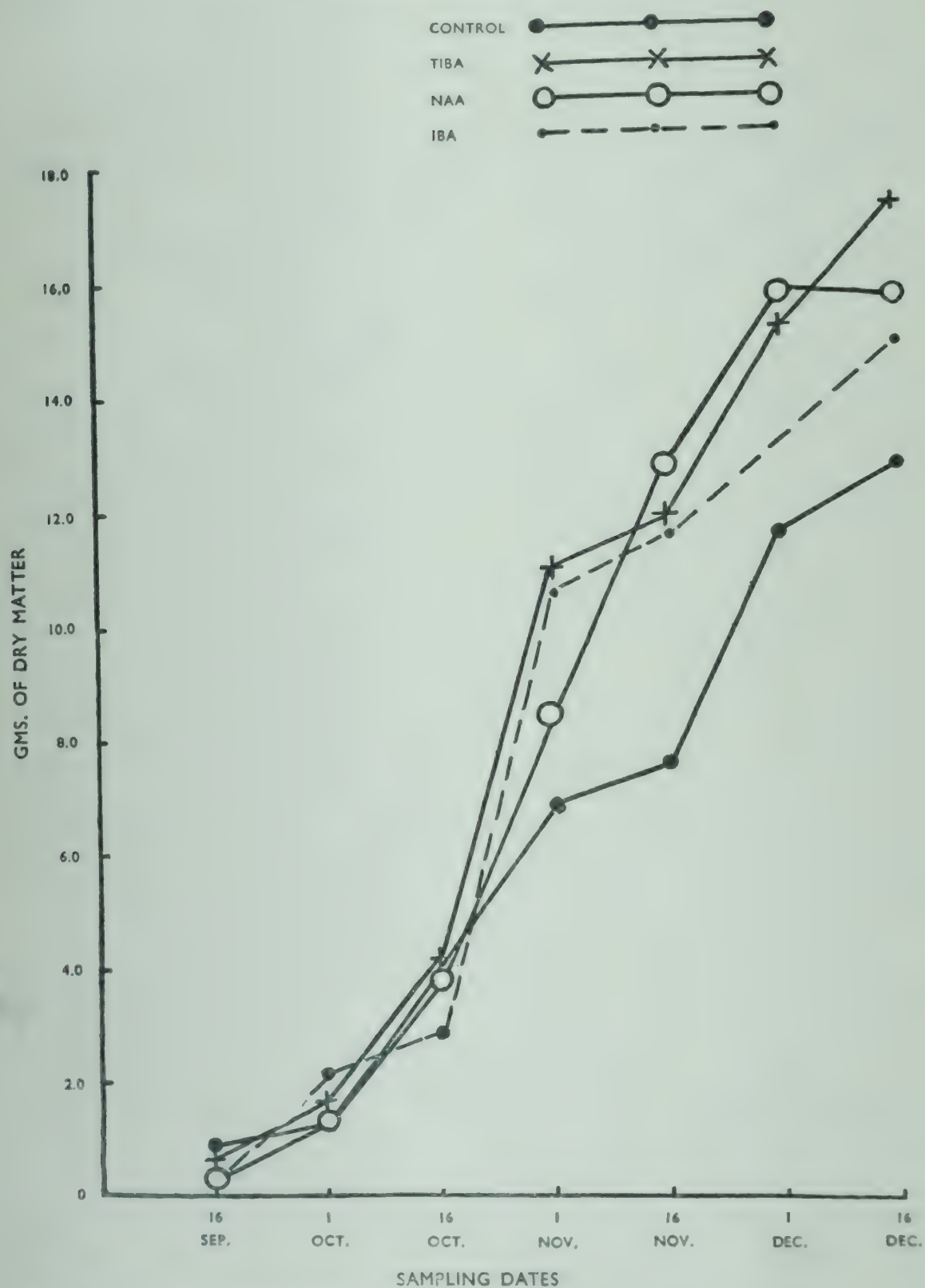


Fig. 14. Dry Weight of the Flowering Parts

mones was seen up to the 1st October. Some enhancing effect of the leaves became visible during the next stage, i.e., the 16th October and the 16th November. There was thus an indication that the leaf growth was favourably affected at the stage when the leaf growth reached its maximum. As the leaf weight was known to be proportional to the leaf area, the total leaf area was higher in the treated plants than the control plants at the time of maximum leaf area stage. The greater leaf area and consequently greater photosynthetic activity on account of hormone application resulted in better flowering and fruiting activity in the treated plants. The dry weights of the flowering and fruiting parts of the hormone treated plants were higher than the dry weights of the corresponding parts in the untreated plants during the last four stages, i.e., from the 1st November to the 16th December. All the three hormones had enhanced the fruiting activity and greater dry matter per plant produced under each hormone treatment was mainly due to the greater dry weight of the reproductive parts (Fig. 14).

When the dry weight of the reproductive parts was calculated per 100 gm. of the total dry weight of the plant under each treatment, it was found that the treated plants produced greater percentages of the dry weights of the reproductive parts than those of the control plants (Fig. 15). Thus it was definite that the main effects of these hormones were on photosynthetic activity resulting in greater production of dry matter; especially the dry matter of the reproductive parts. The efficiency of the cotton plant for reproductive growth was thus greater in the hormone treated plants.

The differences in the total dry weight per plant between the control and the hormone treated plants were found to be statistically significant (Table 21). As four plants from each replicate were weighed separately, the means of the total dry weight per plant under each treatment on the sampling dates are given.

TABLE 21. MEAN OF TOTAL DRY WEIGHT PER PLANT (IN GM.) UNDER EACH TREATMENT ON SAMPLING DATES

Date	Control	TIBA	NAA	IBA	S.E.	C.D. 5%
16th October	10.05	12.64	12.15	11.42	1.76	2.99
1st November	15.32	22.22*	16.58	19.23	2.43	5.50
16th November	15.76	20.39**	20.80**	20.34**	0.70	1.50
1st December	19.25	21.35	25.92*	20.33	2.13	4.83
16th December	20.09	23.58	26.70*	23.12	1.58	3.57

* Denotes significance at 5 per cent. level.

** Denotes significance at 1 per cent. level.

Even though spraying was done on the 8th August the differences in the total dry weight per plant began to appear after the 16th October. The significant differences in the dry weights under each hormonal treatment can be seen from Table 21. The TIBA and NAA treated plants produced signifi-

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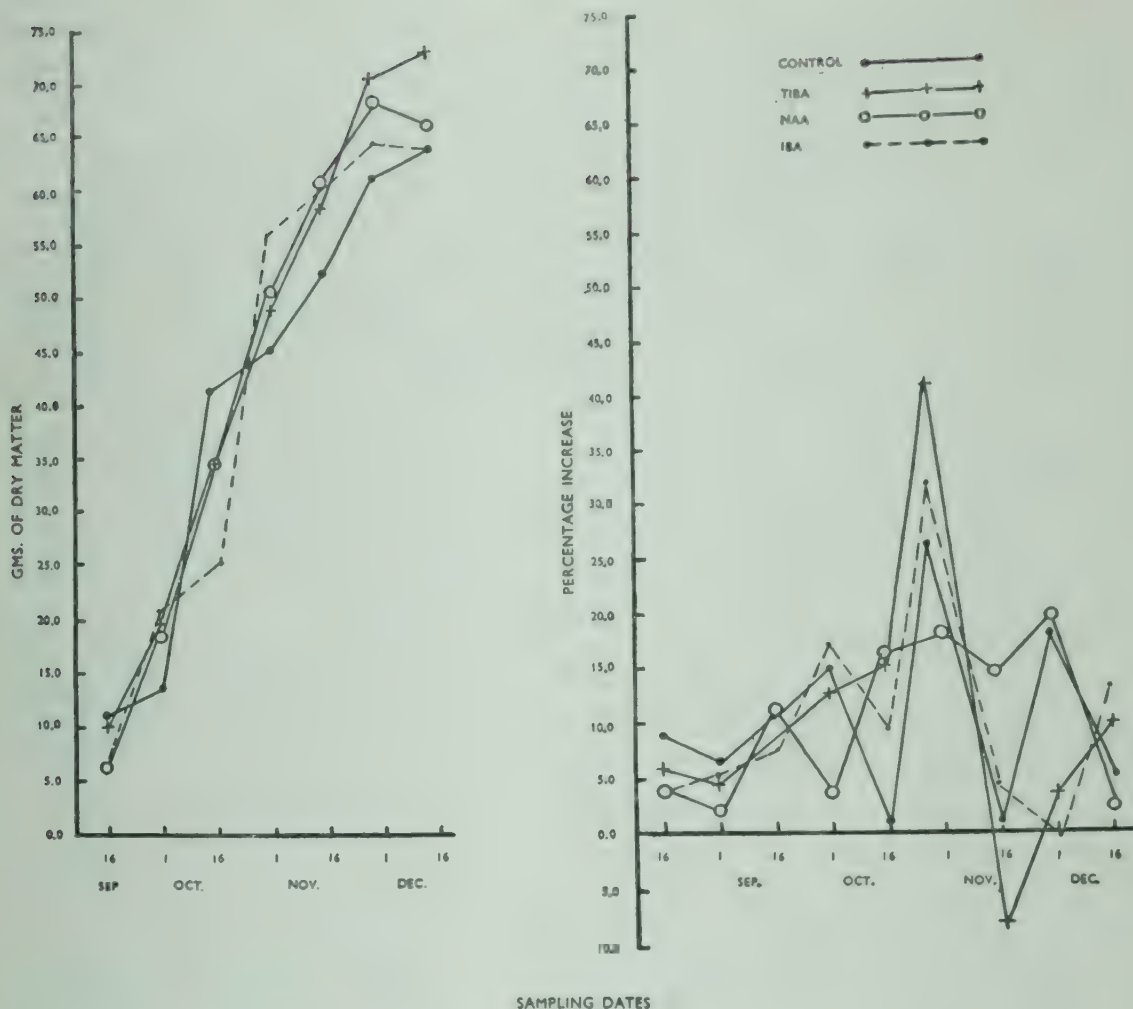


Fig. 15. *Left:* Flowering Parts per 100 gm. of Total Dry Weight

Right: Percentage Increase in Total Dry Weights

cantly higher dry weights than the control plants while the effect of IBA was significant only on one date. The differences between the total dry weights per plant, between the control and treated plants, were mainly due to the differences in the dry weight of the reproductive parts (Table 22).

TABLE 22. MEANS OF DRY WEIGHTS OF REPRODUCTIVE PARTS (IN GM.) AT EACH SAMPLING DATE

Date	Control	TIBA	NAA	IBA	S.E.	C.D. 5%
16th October	4.220	4.422	4.122	2.965	0.619	1.399
1st November	6.885	10.815*	8.508	10.658*	1.459	2.391
16th November	7.680	11.582**	12.582**	11.778**	0.501	1.132
1st December	11.788	15.015*	17.701*	13.078	1.397	4.466
16th December	12.645	17.023**	17.590**	14.670**	2.116	0.696

* Denotes significance at 5 per cent. level.

** Denotes significance at 1 per cent. level.

The effect of TIBA only on the dry matter of the reproductive parts was significant from the 1st November onwards while the effect of NAA came out significant from the 16th November onwards. Thus these two hormones

had definitely increased the reproductive growth on the 1st November and the 16th December. On account of a high error the effect of IBA has not reached the level of significance in the sample collected on the 1st December.

Though there appeared to be no accumulation of nitrogen either in the leaf or in the stem when the plants were treated with chemical hormones as reported by various workers the total nitrogen contents of the reproductive parts of the control and hormone treated plants showed marked differences from the very beginning of the flowering and fruiting activity. The total nitrogen contents of the reproductive parts were found to be at a higher level from the early stage up to maturity in the hormone treated plants than in the control plants even though the trends in total nitrogen were similar. The plants treated with TIBA showed highest concentration of nitrogen. Thus hormone treatment produced greater concentrations of the reducing sugars and nitrogen in the reproductive parts.

The effect of all the hormones on the protein nitrogen content was clear from the very early stages. Like the carbohydrates the protein nitrogen content was higher in the leaves of the hormone treated plants than in the leaves of the control plants, during the period of maximum activity. Though the results of the total nitrogen did not indicate any differences between the treatments, presence of more proteins in the leaves from the 16th August to the 16th October indicated that more nitrogen was converted into proteins in the treated plants than in the control plants.

It, therefore, appeared from the results that the control plants contained more of non-protein nitrogen in the leaves while all the nitrogen in the hormone treated plants was in the form of proteins. These results indirectly suggest that more carbohydrates were available for protein synthesis in the treated plants than in the control plants.

The stems of hormone treated plants did not show greater accumulation of the proteins than those of the control plants.

The protein nitrogen of the reproductive parts under hormone treatment showed depression on the 1st October and this depression corresponded with a similar depression noticed in the total carbohydrate contents on the same date. This was the only difference. The protein nitrogen content of the reproductive parts of the hormone treated plants stood higher at all stages except on the 1st October.

There was thus a higher rate of carbohydrate synthesis and consequently of protein synthesis on account of the application of hormones. It, however, remains to be investigated in what manner those hormones accelerate synthesis of carbohydrates.

YIELD OF SEED COTTON UNDER FIELD CONDITIONS

Some of the beneficial effects observed in pot culture experiments with hormones and the subsequent investigations of their effect on carbohydrate

and nitrogen metabolism in the cotton plant indicated the possibilities of similar beneficial results from field trials. Results of successful application of NAA in increasing yield of seed cotton in Bhoj were first reported by Bhatt and Date (1955). Bhatt (1958) also confirmed this beneficial effect of NAA on Bhoj (*G. arboreum*) in two more cotton seasons along with several other plant hormones (Table 23). Similar experiments were conducted side by side on the American variety Indore 1 but there was no consistent response on yield in this variety in Malwa tract or Dharwar or at Mysore. Negi and Singh (1956) on the contrary, noted the beneficial effect of planofix containing alfa-naphthalene acetic acid on 216F Punjab-American cotton. It is difficult in the present state of knowledge to explain the reasons for contrary results obtained with the American variety. As consistent effect on the yields of *desi* variety was obtained for three successive seasons, these results are given below (Table 23).

TABLE 23. EFFECT OF ALFA—NAPHTHALENE ACETIC ACID ON YIELD OF BHOJ (DHAR 43)

Concentrations	Yield of seed cotton (lb. per acre)	
1953-54 Season		
	Early spraying	Late spraying
Control	466.2	466.2
10 p.p.m.	567.6	582.6
20 p.p.m.	537.6	593.2
30 p.p.m.	516.6	569.1
	S.E. \pm 45.8	C.D. \pm 97.5
1954-55 Season		
Control	314.6	314.6
15 p.p.m.	374.7	354.5
10 p.p.m.	421.4	439.2
20 p.p.m.	463.9	402.5
	S.E. \pm 30.9	C. D. \pm 90.6

EFFECT OF 10 P.P.M. CONCENTRATION OF SEVERAL PLANT HORMONES ON YIELD (1955-56)

Treatments	American (Indore 1)	Desi Bhoj (Dhar 43)
Control	166.8	155.4
2, 4 dichloro-phenoxy acetic acid	136.8	176.6
B-3 indolyl propionic acid	169.5	183.7
A-3 indole acetic acid	150.7	194.8
A-3 indole butyric acid	142.5	144.7
Phenoxy acetic acid	166.7	212.1
A-naphthalene acetic acid	176.7	232.9
2, 3, 5 tri-iodo-benzoic acid	147.9	194.1
	S.E. \pm 14.5	C.D. 5% 16.9

Field experiments with the plant hormones thus revealed that only *desi* variety had so far responded consistently showing significant increases in yield of seed cotton for three successive seasons. Late spraying of NAA, i.e., at the commencement of the reproductive phase appeared comparatively better than early spraying, i.e., at the vegetative phase. Optimum dose for NAA on *desi* cotton appears to be 10 p.p.m. and the application is found to be economically beneficial. It is necessary to repeat these trials on *desi* cottons before any final recommendations regarding the use of this hormone can be taken up on a practical scale.

BUD AND BOLL SHEDDING

A preliminary inquiry into the problem of the bud and boll shedding in cotton was first made by Hilson *et al.*, (1925) at Coimbatore. Cambodia cotton (*G. hirsutum*) and progeny plants of the ninth generation of a cross between Cambodia and Bourbon cotton (*G. purpurascens*) were used. This inquiry had as its main object, isolation of a strain of cotton with a low shedding index. The investigation was, therefore, not intended to determine the causes behind the physiology of the bud and boll shedding as much of the shedding which occurred in the second flush as compared to the first flush was attributed to heavy attacks of insect pests. A tentative correlation between the temperature and the length of interval of shedding was also attempted.

Joshi *et al.*, (1941) observed that flower buds incepted early and late in the season were always shed at one time or another while only some belonging to the intermediate period grew into bolls. The boll shedding was very low in the beginning and increased with the advance of the season.

As a result of three years' study Joshi *et al.*, (1941) concluded that improvement of available moisture in the feeding zones of the soil by frequent application of water in increasing quantities to two acre-inches per month consistently failed to reduce the bud and boll shedding. In Broach cotton tract deficiency of available water in the soil was thus not found to be the causal factor of the incessant shedding of the buds and young fruits. There was, however, a tendency for the boll production to increase with the application of larger quantities of water.

Application of nitrogen during the flowering period increased the production of flowers and bolls without reducing the extent of shedding. The nitrogen applied during the bolling period only enhanced the number of flowers and bolls and increased the yield of seed cotton per boll; in this case the extent of shedding was also reduced and the percentage of nitrogen in the seed increased.

Removal of the flower buds over various periods prolonged life cycle of the plant by promoting vegetative growth as well as the production of flower buds. Debudding increased the leaf area and, therefore, food supply, and thus a larger number of the flower buds developed into flowers. However,

boll development from these flowers produced late in the season suffered because conditions for photosynthesis were not favourable at that time.

Heavy bud shedding at any time did not lead to reduction of mature bolls.

In absence of the developing bolls in the plant in the early period by deflorating, flowers formed later were induced to mature in to bolls. It is, therefore, implied that heavy boll shedding usually occurring during the latter part of the flowering season was brought about by diversion of food to developing bolls set earlier.

Ringling of the main stem hastened flowering as well as slightly increased the number of flowers; however, the number of bolls was reduced.

Root pruning shortened the period of flowering but raised their number.

Late sowing increased the proportion of the vegetative buds to flower buds and also the success of the flower buds to flowers. However, formation of the bolls was not improved and thus the boll number was little affected or slightly reduced by late sowing.

Wide spacing (3' x 3') increased the percentage success of buds into bolls as compared to close spacing (3' x 1').

Joshi *et al.*, (1941) opined that shedding of the buds which appears quite early in the season is due to uncongenial quality of the sap and that the subsequent shedding of both the buds and bolls which occurred incessantly throughout the period of their formation is the result of food shortage in the plant. It was emphasized that the shedding of the reproductive organs which takes place in the natural course of growth adjustment need not be viewed with concern.

Their explanation with regard to early shedding of buds was based on the changes in the carbohydrate/nitrogen ratio caused by the changes in the carbohydrate concentration on account of seasonal conditions that prevail during the months of September and October.

Dastur and Mukhtar Singh (1943) and Dastur and Gopani (1952) in their studies of the growth of cotton in the Punjab and at Surat, respectively, have shown that though the application of nitrogen increased the number of flowers and bolls per plant, the setting percentage as compared to the untreated plants remained unaffected. Dastur and Kanwar Singh (1956) have also obtained similar results at Indore except in 1950-51 cotton season when nitrogen was found to increase slightly the setting percentage.

To sum up the work done in India and abroad, the physiological causes of the bud and boll shedding are still unknown. From 1922, Mason and Maskell's finding gained ground that the cotton plant retains only as many bolls as it can supply with carbohydrates, nitrogen or other nutrients. Eaton and Ergle (1953) reported that different levels of water supply, gridling and daily spraying with urea had no effect on boll setting even though there were marked increases in nitrogen content and carbohydrate accumulation by

gridling. Eaton and Ergle (1953) found more or less similar fruitfulness with growth variations as conditioned by varying levels of moisture, nitrogen, sulphur and molybdenum; boll shedding was nominal until a good many bolls had set. It was, therefore, postulated that an antiauxin is produced by older fruits which interacts with the auxin produced by the leaves and thus the abscission of young fruits is regulated. Observations made by several workers lend support to this view. However, Eaton and Ergle (1953) conclude that the cause or causes of boll shedding are unknown. Within a variety and climatic complex (and largely independent of the nutritional status) the number of bolls that is set tends to be proportional to the weight of leaves and stem, provided that the spacings of the plants are the same and the day length and temperature are suitable for the formation of the fruiting branches. The mechanism of the formation of the fruiting branches remains as yet a problem for investigation and also that of the prevention of over-fruiting through boll shedding.

PHYSIOLOGY OF 'BAD OPENING' OF BOLLS IN PUNJAB-AMERICAN COTTONS

RELATION OF SOIL CONDITIONS TO 'BAD OPENING'

The Punjab-American cottons in the Punjab suffered from a physiological disease popularly known as *tirak* or 'bad opening' of the bolls. The cotton crop which was generally sown in May appeared healthy and normal up to September when the crop was in the flowering stage. The symptoms of this disease first appeared in the leaves which began to turn pale green and yellow. This was followed by reddening and shedding of the leaves. The bolls of such plants remained small and cracked prematurely, i.e., before their normal period of maturation (52 days) was completed. The cotton seed in such bolls was partially or fully immature and bore very trashy lint. The lint did not fluff out of these bolls as in the case of the normal bolls. The percentage of oil in the seeds from such bolls was much lower than in the seeds from the normal bolls. The weight of *kapas* per boll was, therefore, considerably lowered. Normally 400 to 500 bolls were required to yield 2 lb. of *kapas* while any number from 600 to 2,000 bolls depending on the intensity of the disease was required to yield the same quantity of *kapas* when *tirak* occurred. The general level of cotton yields in such fields was, therefore, lower than what it would be if the crop was not subject to this trouble. A field that would normally yield 800 lb. of *kapas* per acre gave even as low a yield as 150 lb.

Tirak in a very intense form occurred in 1921, 1927, 1928, 1932 and 1939 and the yield of *kapas* per acre for the province was reduced to about three maunds. These years were named as the years of partial failures of American cotton in the Punjab.

The extent of loss suffered on account of this disease can be judged from the total acreage under American cotton in the Punjab. The acreage under

these cottons fluctuated from one to one and half million from year to year and a depression in yield of even one maund per acre would cause great losses to the cotton growers.

Preliminary observations made in the early stages of this investigation paved the way to the discovery of the causes of this physiological disorder. Microscopic examination of the leaves of *tirak* plants showed the accumulation of a chemical substance in their tissues (Plates Ib and IIa) (Dastur, 1939). *Tirak* was found to occur, in many cases, in the same field every time cotton was grown there. It was also observed that the cotton crop showed *tirak* in one part of the field while the crop was normal in another part of the same field. The intensity and spread of *tirak* in a field were also found to vary in the different seasons.

The first observation led ultimately to the discovery of nitrogen deficiency in the plants that showed the symptoms of *tirak* (Dastur, 1941). The deficiency of nitrogen in plants generally occurred in light sandy soils and the crop on such lands showed the symptoms. The second set of observations led to the discovery of the presence of sodium salts in abnormal amounts in the sub-soil at a depth of two or three feet from the soil surface. Thus two types of soils were found to be associated with *tirak*: (i) light sandy soils with nitrogen deficiency; and (ii) sandy loams with salinity in the sub-soil. It was later found that light sandy soils deficient in nitrogen were at the same time saline in the sub-soils and the worst form of *tirak* occurred in such fields. Soils under normal and healthy crops were neither saline nor did they produce a deficiency of nitrogen in the plants during the fruiting stage.

As the work progressed it was discovered that normal soils, soils with saline sub-soil and soils deficient in nitrogen were, many a time, found intermingled in a small area measuring about $2\frac{1}{2}$ acres or less. Consequently a great deal of confusion was caused in correlating the soil conditions with the normal or the abnormal behaviour of the crop.

Light Sandy Soils. The cotton soils in the Punjab contain a large proportion of sand and a smaller one of clay. The percentage of sand in light sandy soils was nearly 70 in the upper surface. Under normal conditions of irrigation which ensured a regular supply of water and with long and bright summer days which are favourable for the food manufacturing processes in the leaves, the American cotton plants made rapid growth. The nitrogen in the soil was adequate for the vegetative growth of the plants and the crop, therefore, showed no symptoms of *tirak* till the regular flowering phase set in at the end of August. At this stage the demand for nitrogen became high as it was needed for the production of flowers and fruits and it was not met from the soil. The nitrogen present in the leaves travels towards the fruiting parts and the leaves get depleted of its nitrogen as it is not replenished by absorption from the soils. The loss of nitrogen caused earlier senility of the leaves which turned yellow and were shed. When the leaves

are shed other non-nitrogenous food substances and minerals are also lost to the plants.

The analysis of the leaves in the month of September from such fields showed that their nitrogen content had fallen to 1.5 per cent. or less which was much below the amount found in the leaves of the normal plants. The level of nitrogen in the leaves should not fall below 2.5 per cent. during the fruiting stage for proper maturation of the bolls.

When the nitrogen contents of the leaves fell below normal an organic substance known by the general name 'tannin' was found to accumulate in their tissues (Plate IIb). Table 24 gives the percentage of nitrogen in the leaves and the positive and negative tests for 'tannin'. The positive tests for 'tannin' are given when the total nitrogen was below 2.5 per cent.

TABLE 24. TOTAL NITROGEN CONTENT OF LEAVES WITH A POSITIVE OR NEGATIVE TEST FOR 'TANNIN'

	26-8-1938		20-9-1938		20-10-1938		Weight of seed cotton per boll (gm.)	Yield per plot (lb.)
Plot No.	Per cent. of N	Tannin	Per cent. of N	Tannin	Per cent. of N	Tannin		
<i>Control</i>								
1	2.58	—	1.82	+	1.46	+	1.56	15.8
4	2.99	—	2.26	+	1.62	+	1.55	13.1
16	2.54	—	1.71	+	1.57	+	2.06	15.6
20	2.82	—	1.65	+	1.22	+	1.85	18.8
39	1.97	+	1.51	+	1.23	+	1.61	16.6
50	2.42	+	1.71	+	1.15	+	1.84	16.3
62	2.52	—	1.71	+	1.31	+	1.31	15.4
Mean	2.55		1.76		1.36		1.68	15.9
<i>50 lb. Nitrogen at Sowing Time (16-5-1938)</i>								
18	3.34	—	3.15	—	2.32	+	2.15	31.0
13	3.22	—	2.81	—	2.31	+	1.83	25.6
49	—		2.65	—	1.85	+	2.44	35.5
32	2.69	—	2.20	+	1.75	+	2.16	36.2
45	—		2.69	—	1.70	+	2.21	32.3
59	3.46	—	2.67	—	1.98	+	2.36	31.0
52	2.98	—	2.66	+	2.03	+	2.22	32.6
64	3.27	—	2.85	—	2.01	+	2.31	35.3
Mean	3.16		2.71		1.99		2.21	32.4

The accumulation of this substance produced other disorders in the plant. This substance was first noticed in the tissues of the leaves under the microscope and later it was found to be a bio-chemical index of a deficiency of nitrogen in the plant (Plate IIc) which can be identified microscopically.

The chemical nature of this substance tentatively called 'tannin' is not yet determined. It is provisionally called 'tannin' as it gave a black colour with osmic acid. It is possible it may be an amino acid or a substance containing polyhydric phenolic groups. Further work has shown that there

are two substances which reduce osmic acid, one giving green colour and the other black colour. The word 'tannin' refers to the second type of substance.

The low nitrogen level, the production of 'tannins' in the tissues and the premature senility and loss of leaves caused poor development of cotton bolls. The seeds, therefore, remained partially immature. The final result was *tirak* or 'bad opening' and low yields (Table 24).

Soils with Saline Sub-soil. The nature of physiological disorder that developed in cotton plants growing on such lands was different though the end result was the same, viz., the premature shedding of the leaves and small bolls with immature seeds and poor quality of lint. On this type of soil the plants made normal growth up to September. This was the stage when the plant had produced the maximum number of leaves. At this stage the plant began to show signs of water shortage (Plate IIIb). The moisture from the first two feet of the soil dried up a week after the usual irrigation was given and the water lost by transpiration (evaporation) from the leaves was not replaced by absorption from the soil. The presence of salinity in the sub-soil from the third foot interfered with absorption of water by the roots from those deeper layers of the soil. Thus a condition of physiological drought developed. Though the moisture was present in the sub-soil it was not available to the plant on account of the saline sub-soil. The leaves, therefore, lost their turgidity for the lack of moisture, began to assume a drooping position and remained in that position for all the hours of the day and night (Plate IIIb). This did not happen on normal (non-saline) lands (Plate IIIa). The drooping leaves were gradually shed.

The difference between the normal soil where *tirak* did not occur and where sub-soil salinity was associated with *tirak* can be seen from Tables 25 and 26. The total salts were in abnormal quantities in *tirak* patches from the third foot downwards. Further analysis revealed that these salts were sodium salts in the form of chloride, sulphate and carbonates. In some cases sodium had entered the clay complex by replacing calcium in the clay complex.

It was also found that the degree of sub-soil salinity varied in the same field within a distance of a few feet. One spot may contain much less total sodium salts than the adjoining spot. Some spots may be normal. Thus the soils were chequered in nature.

Once the balance between the demand and supply of water was upset other physiological activities of the plant were adversely affected. The leaves became functionless and lost their capacity for manufacturing plant food. This in turn affected the growth of the plant and especially its fruiting parts. The bolls remained small with immature seeds inside for lack of important nutrients.

TABLE 25. SOLUBLE AND EXCHANGEABLE *SODIUM AND CALCIUM IN SOILS UNDER TIRAK-AFFECTED AND NORMAL CROPS

Depth	Per cent. Total solids	Per cent. Sol. Na.	Per cent. Sol. Ca.	Exchangeable		Per cent. Total solids	Per cent. Sol. Na.	Per cent. Sol. Ca.	Exchangeable	
				Na+K m.e.	Ca. m.e.				Na+K m.e.	Ca. m.e.
<i>Tirak</i>										
	Sargodha					Lyallpur				
1st foot	0.063	0.003	0.008	1.05	9.4	0.037	0.003	0.008	0.9	9.8
2nd "	0.058	0.008	0.007	0.88	11.2	0.076	0.029	0.006	1.1	11.6
3rd "	0.147	0.014	0.005	2.12	9.2	0.497	0.148	0.047	Nil	11.2
4th "	0.235	0.059	0.004	3.00	7.21	0.583	0.155	0.039	"	9.2
5th "	0.304	0.062	0.008	2.12	6.8	0.581	0.167	0.029	"	7.8
6th "	0.242	0.060	0.005	1.35	6.0	0.375	0.148	0.013	4.2	5.6
<i>Normal</i>										
	Sargodha					Montgomery				
1st "	0.055	0.003	0.014	0.60	10.6	0.080	0.003	0.010	0.8	6.6
2nd "	0.063	0.003	0.012	0.48	12.4	0.098	0.002	0.009	0.8	7.0
3rd "	0.068	0.003	0.015	0.54	13.4	0.086	0.001	0.008	0.6	7.6
4th "	0.058	0.003	0.013	0.65	13.4	0.094	0.002	0.009	0.4	8.4
5th "	0.067	0.004	0.015	0.48	12.6	0.098	0.001	0.008	0.6	8.4
6th "	0.067	0.003	0.013	0.43	10.3	0.094	0.001	0.008	0.6	7.2

* Exchangeable potassium is generally 0.2 to 0.5 m.e. per 100 gm. of air dry soil.

TABLE 26. TOTAL SOLUBLE SALTS IN THREE BORES OF TIRAK-AFFECTED PATCHES (gram per 100 gm. of soil)

Depth	Bore No.			Bore No.			Bore No.		
	I	II	III	I	II	III	I	II	III
	Khanewal			Montgomery			Sargodha		
1st Foot	0.049	0.044	0.046	0.057	0.060	0.044	0.064	0.067	0.088
2nd "	0.045	0.100	0.057	0.092	0.056	0.047	0.058	0.056	0.057
3rd "	0.049	0.146	0.052	0.154	0.382	0.059	0.147	0.082	0.074
4th "	0.140	0.135	0.083	0.175	0.439	0.066	0.235	0.061	0.081
5th "	0.479	0.140	0.156	0.513	0.303	0.056	0.304	0.154	0.109
6th "	0.310	0.160	0.306	0.444	0.229	0.054	0.242	0.175	0.288

The time and extent of the water deficiency that will arise in a cotton crop in a field with salinity in the soil depend on a number of factors. They were the size of the plant's body, the physical texture of the soil, the degree of salinity, the nature of sodium salts present and their relative amounts. The development of *tirak* and its intensity would, therefore, depend on the combined effect of all these factors of which salinity was the chief determining factor.

PHYSIOLOGICAL CHEMISTRY OF TIRAK-AFFECTED PLANTS

Though there were no differences in the stems and roots between normal and *tirak*-affected plants, marked differences in the concentrations of nutrients and other organic substances in the leaves of *tirak*-affected plants growing

on two soil types were found to exist. The leaves of *tirak*-affected plants contained less nitrogen and lime from the early stage of growth and less potash from the flowering stage (Dastur and Ahad, 1945), than the leaves of plants growing on normal sandy loam soils.

The above quoted results indicated some disturbance in the uptake of minerals on the two soil types where *tirak* occurred. If immaturity of the seeds was a direct or an indirect effect of deficiency of any one of the important minerals, it should also be possible to detect them in the developing bolls. A study of the metabolism of the developing bolls was, therefore, considered necessary. A normal field, a field where *tirak* occurred on account of salinity in the sub-soil and a field where *tirak* occurred on account of deficiency of nitrogen were selected. Weekly samples of the developing bolls, after they were set, were taken from each field for analysis up to the time the bolls opened.

The following were found to be the important differences between the mineral contents of bolls from normal and *tirak*-affected plants on the two soil types.

A low nitrogen content at all stages of growth in the carpels, seeds and lint was a feature of *tirak*-affected bolls on light sandy soils. The carpels and lint of *tirak*-affected bolls on soils with saline sub-soil on the other hand showed higher nitrogen contents than the corresponding parts of normal bolls at all stages of growth. That was not the case with seeds which, like the seeds from the light sandy soil, contained less nitrogen than the seeds of normal bolls after the third week of development.

Phosphoric acid content was also found to be below normal in the seeds of *tirak*-affected bolls in the last four stages of development under the light sandy soils; the same mineral was, however, found to be present in larger concentration in the carpels from both the soil types and also in the seeds of *tirak*-affected plants from soil with a saline sub-soil.

The carpels of *tirak*-affected bolls were found to contain less potash at all stages than the carpels of normal bolls and this difference in potash contents between normal and *tirak*-affected bolls became more pronounced in the final stages of development. Potash continued to increase in the carpels of normal bolls while it remained constant in the carpels of *tirak*-affected bolls during the last three weeks of boll development.

The lime contents of the seeds and lint in the later stages of growth were higher in *tirak*-affected bolls than in normal bolls.

A low potash content in the carpels and a low nitrogen and high potash and lime contents in the seeds were the common features in which *tirak*-affected bolls differed from the normal bolls.

As the immaturity of the seeds occurred on two different soil types it was possible that the chain of events leading to the development of the common symptom on the two soils may be quite different. It may also be men-

tioned here that the intensity of *tirak*, i.e., the degree of immaturity of seeds was greater on the light sandy soils than on soils with the saline sub-soils. From the results discussed above it was clear that a general deficiency of the nutrients was found to occur in the cotton plants on the light sandy soils and the application of nitrogen in the form of sulphate of ammonia to light sandy soil ameliorated *tirak* occurring on such soils. It was also found that when nitrogen was applied, there was an increase in the uptake of potash and lime by the plants along with that of nitrogen. It, therefore, appeared probable that the uptake of potash and lime was influenced by the level of nitrogen in the soil. The deficiency of potash in the leaves and bolls and of lime in the leaves on the light sandy soils may thus arise indirectly on account of a deficiency of nitrates in the soil.

The case was different with the soils with saline sub-soils where a direct deficiency of nitrogen was not found to occur. In this case the immaturity of seeds was not reduced by the application of nitrogen. It, therefore, appeared probable that the immaturity of seeds was associated with low potash content of the leaves and carpels of *tirak*-affected plants.

The association of the immaturity of seeds with low potash content has already been known in the case of other crop plants (Russel, 1937). Neal and Gilbert (1935) showed that the application of potash remedied the disease of cotton known as 'cotton rust' or 'potash hunger' where the seeds remained immature. Skinner and Pate (1925) found an increase in the boll weight as a result of potash application to fine sandy soils. A decrease in the weight of seeds was reported by Wood (1934) when potash was omitted from manurial experiments.

Though nitrogen was found to be low in the leaves, no deficiency of nitrogen in the carpels of bolls from saline soils was found to occur. There was an accumulation of nitrogen in the carpels but the potash content was below normal. Thus *tirak*-affected bolls from both the soil types showed a low potash content both in the leaves and carpels and potash appeared to be related to immaturity of seeds.

Potash content of the carpels of *tirak*-affected bolls, determined repeatedly, was found to be significantly lower than potash content of the carpels of normal bolls. The difference between nitrogen contents of the carpels of normal and *tirak*-affected bolls was, however, not constant depending on the nature of the soil type from where the samples were collected.

A deficiency of potash or nitrogen had already been known to cause a reduction in the synthesis of proteins and to an accumulation of soluble forms of organic nitrogen, especially in the form of amino acids and amides. The total nitrogen, protein nitrogen and soluble non-protein nitrogen were, therefore, determined at weekly intervals from the carpels, seeds and lint of *tirak*-affected bolls from the two soil types and of normal bolls. The soluble

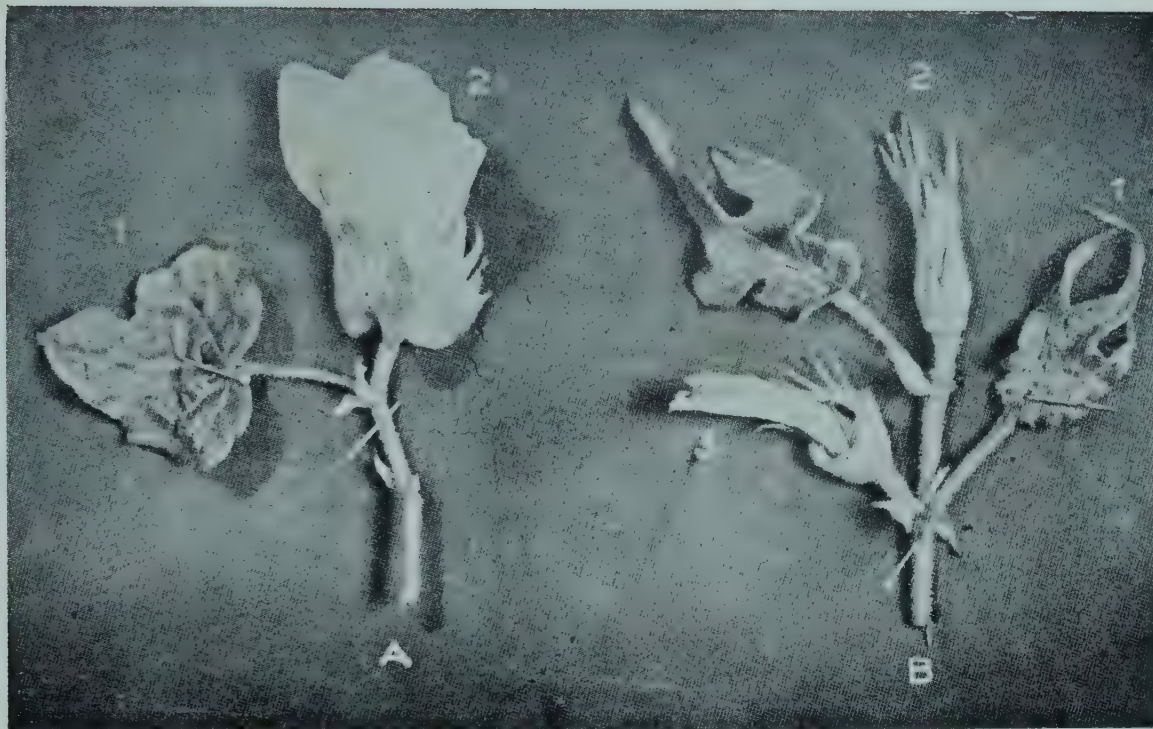
non-protein nitrogen was further analysed for amino nitrogen, amide nitrogen, diamino nitrogen, ammonical nitrogen and nitrate nitrogen.

Though the trends in the total and protein nitrogen contents of the carpels and seeds of bolls of normal and *tirak*-affected plants were similar, there were marked differences in the actual quantity of each found at different stages of growth. The total and protein nitrogen declined in the carpels as the bolls developed but in the case of seeds the total and protein nitrogen began to increase after the third week of development. The concentrations of total and protein nitrogen were highest in the carpels of *tirak*-affected bolls from soil with saline sub-soil, medium in the carpels of normal bolls and least in the carpels of *tirak*-affected bolls from light sandy soils. A nitrogen deficiency was, therefore, evident in the bolls from light sandy soils while an accumulation of nitrogen occurred in the carpels of bolls from saline soil. The case with the protein nitrogen content of the seeds was different. The protein content was highest in seeds of normal bolls, medium in the seeds of bolls from saline soil and the least again in the seeds of boll from light sandy soil. Thus the seeds of *tirak*-affected bolls showed a low protein content as compared with the protein content of the seeds from normal bolls. The protein nitrogen did not increase in the seeds of *tirak*-affected bolls in the last three weeks of development, while proteins continued to be synthesised in the seeds of normal bolls up to the last week of development. The potash content of the carpels of *tirak*-affected bolls had similarly remained constant in the last three weeks of development, while it continued to increase up to the last stage of development in the carpels of bolls from normal plants.

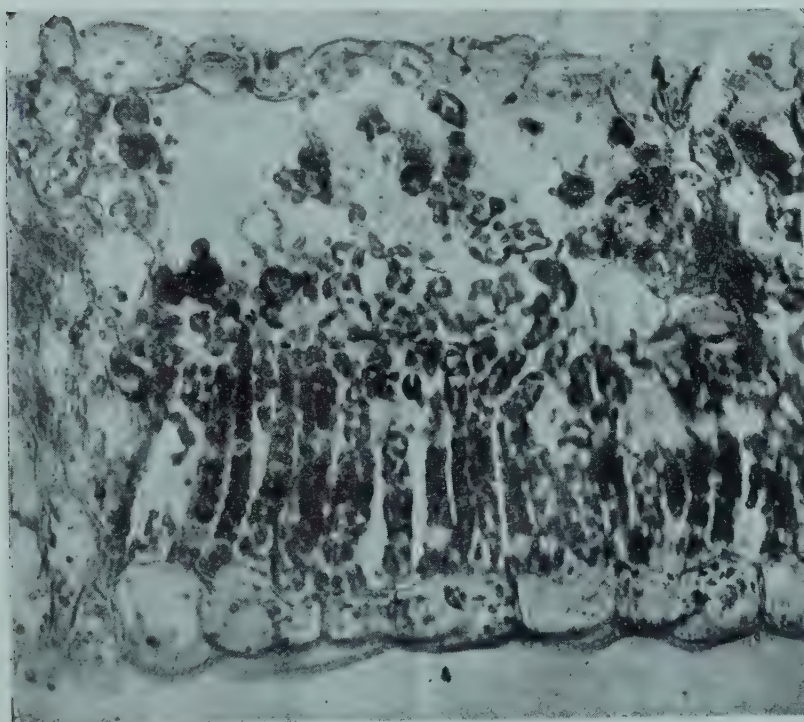
The soluble nitrogen in the carpels of normal bolls began to decrease from the fifth week while it showed an increase up to the last stage of development in the carpels of *tirak*-affected bolls. A continuous decline in the soluble nitrogen in the seeds of normal bolls occurred from the first week up to the last week of development while it increased in the seeds of *tirak*-affected bolls from the fifth week. The accumulation of soluble nitrogen in *tirak*-affected bolls preceded the cessation of the protein synthesis as no increase in protein content occurred from the sixth week. The protein metabolism in the bolls of *tirak*-affected plants did not, therefore, follow the normal course after the fifth week.

A study of the diamino nitrogen contents of the carpels and seeds suggested that the synthesis of proteins in *tirak*-affected bolls did not proceed beyond the diamino stage. The diamino nitrogen in the seeds of normal bolls was markedly higher in the last four weeks than that of the seeds of *tirak*-affected bolls even though the total soluble nitrogen (which included diamino nitrogen) was lower in the seeds of normal bolls during the same period.

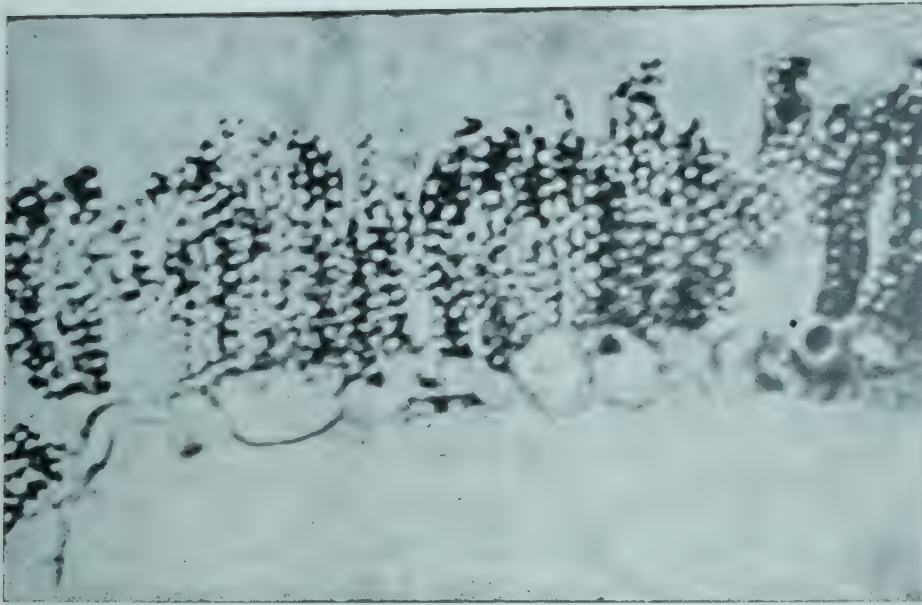
Nitrates, ammonia, amino acids and amides accumulated from the fifth or the sixth week in the seeds and carpels of *tirak*-affected bolls, while these forms of soluble nitrogen (except nitrates in the carpels) showed a con-



a. Changes in Morphological Characters of American Cotton Plant by 2,4-D. A-1. Normal Leaf; 2. Normal Flower. B-1. Modified Leaf; 2. Modified Flower with Sheathing Bract; 3. Bract split open to show Gamopetalous Corolla (See Page 43)



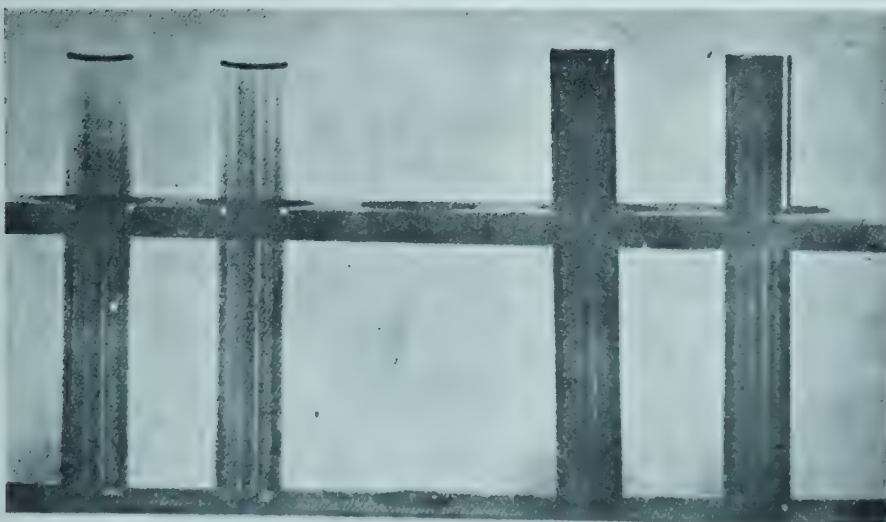
b. Section of Leaf Showing Normal Chloroplasts



a. Section of Leaf Showing Large Starch Grains in Chloroplasts



b. Section of Leaf Showing Thick 'Tannin' Deposits



Negative Test

Positive Test

c. Tannin Test in Extracts of Leaves



a. Normal Cotton Crop Showing Erect and Turgid Condition of Leaves



b. Cotton Crop on a Soil with Saline Sub-Soil Showing Drooping Leaves

PLATE IV



a. May-Sown Cotton Crop on Sandy Loam with Saline Sub-Soil Showing 'Badly Opened' Bolls



b. June-Sown Cotton Crop on Sandy Loam with Saline Sub-Soil Showing 'Well Opened' Bolls

tinuous decline in the carpels and seeds of normal bolls. The accumulation of soluble nitrogen in the carpels and seeds indicated that the synthesis of proteins ceased in *tirak*-affected bolls from the sixth week of development as from that stage the soluble nitrogen was not converted into protein nitrogen. Total soluble nitrogen in the seeds of *tirak*-affected bolls was at a higher level than the total soluble nitrogen in the seeds of normal bolls at all stages of growth indicating that the protein synthesis was not proceeding at the same speed in *tirak*-affected bolls as it did in normal bolls. The cessation of protein synthesis in the seeds also caused an accumulation of the different soluble nitrogen fractions in the carpels. The supply of soluble organic nitrogen greatly declined from the sixth week in *tirak*-affected bolls and this fall coincided with a decline in the concentration of potash. Lack of potash caused a cessation in the protein synthesis and whatever small amounts of soluble nitrogen that reached the bolls remained unconverted into protein and it remained accumulated mostly in the form of diamino nitrogen, amino acids and amides. The seeds consequently remained immature in *tirak*-affected bolls. This appeared to be the probable cause of events but further work is necessary to link up seed immaturity with low potash content.

ARTIFICIAL REPRODUCTION OF TIRAK SYMPTOMS

If *tirak* symptoms in the Punjab-American cottons developed on account of the presence of sodium salts in the sub-soil layers it was necessary to obtain experimental evidence to confirm that view. An experiment was, therefore, laid out where the salts were added below the surface, as under natural conditions total soluble salts were low in the first two feet of the soil but they began to rise from the third foot downwards. Attempt was, therefore, made to reproduce similar rise in the concentrations of total salts from above downwards on a non-saline soil. Sodium chloride and sodium carbonate were the two salts employed as these two have been known in case of other plants to be most toxic in their effect. The treatments were all combinations of sodium chloride and sodium carbonate. The quantities of each salt, required to raise the concentration of each, in each foot of the soil were calculated and used.

The earth up to a depth of four feet was removed in six-inch layers from each plot and heaped separately. The required quantity of each salt for the fifth foot was calculated and added after loosening the soil of the fifth foot. Soil of the last six inches of the fourth foot was replaced in the pit and the required quantity of each salt for that layer was weighed, added and thoroughly mixed with soil. The process was repeated up to the top most layer. The plots were then irrigated. The crop was sown in May. A number of observations were recorded in each plot during the growth of the crop, (Table 27).

TABLE 27. MEAN WEIGHT OF STEM, BOLL NUMBER, WEIGHT OF SEED COTTON PER BOLL AND YIELD

	Weight of stems (gm.)	Boll number per plot	Weight of seed cotton per boll (gm.)	Yield adjusted (lb.)
Control	2781	505.9	0.995	1.11
Chloride	1740	366.9	0.809	0.81
Control	2763	539.8	1.029	1.19
Carbonate	1758	333.1	0.775	0.72
S.E.	± 332.4	± 59.6	± 0.088	± 0.147
Yield differential response ± 0.208				
	Chloride		Carbonate	
Due to	Presence	Absence	Presence	Absence
Chloride	—	—	± 0.02	-0.62
Carbonate	-0.15	-0.79		

The drooping of leaves was found to occur in majority of plots treated with sodium chloride and with the mixture of sodium carbonate and sodium chloride.

The depressing effects of the sodium salts on the dry weight of the stems per plant, yield, boll number and boll weight were clearly visible and these effects were significant. The weight of seed cotton per boll was significantly reduced under these treatments indicating that these salts had produced immaturity of the seeds as they did under natural conditions. Sodium carbonate had proved more harmful than sodium chloride in reducing the boll weight and boll number.

The results of yields were statistically analysed after adjusting the yield for stand by the help of analysis of covariance (Fisher, 1936). The regression of yields on plant number, for plots treated alike, was found to be 0.0769 after eliminating differences due to block and treatments. The correlation between yield and plant number was 0.6609 and was significant.

The two treatments had also significantly depressed the yield. The interaction chloride into carbonate was significant and positive, indicating that carbonate had proved less harmful in the presence of chloride than in its absence.

The experiment clearly indicated that the growth and yields were reduced by the presence of sodium salts. The opening of bolls was bad and the seeds had remained immature when the salts were added. Thus *tirak* symptoms were reproduced by addition of the sodium salts. In the above experiment the doses of salts added were rather heavy and they had proved to be very toxic and the plants were very stunted in size.

In another experiment smaller quantities of salts than those used in the first experiment were applied so that when distributed over a depth of four feet they would be nearly the same as those generally found in patches where

tirak occurred. Sodium sulphate was not included as previous experience had shown that it was not having any effect on the plant in concentrations in which it occurred in such soils. The experiment, therefore, was designed to study the effects of sodium carbonate and sodium bi-carbonate (quality at three levels, zero, single dose, double dose) in combination with three levels, (zero, single dose, double dose) of sodium chloride. The combination, carbonate and bi-carbonate, was automatically excluded. There were thus 18 treatments comprising of all combinations of the following :

<i>Quality</i>	<i>Quantity</i>	<i>Chloride</i>
Sodium bi-carbonate	Single dose	Sodium chloride I
Sodium carbonate	Double dose	Sodium chloride II

All treatments were completely randomised in each block.

The quantity of each salt to be added to the soil was calculated so as to give the required concentration for one acre-foot of soil. The percentage concentration of a single dose of chloride was kept equal to the percentage concentration of a double dose of carbonate or bi-carbonate. The actual quantity of each salt in each dose and its percentage concentration in one acre-foot of soil are given below in Table 28.

TABLE 28. SALT CONTENT IN EACH DOSE AND ITS PERCENTAGE IN ONE ACRE-FOOT OF SOIL

		Actual quantity added (lb. per acre)	Per cent. concentra- tion of salt (per acre- foot of soil)	Per cent. concentra- tion of acid radical (per acre)
Sodium chloride	(single)	8000	0.182	0.109
" "	(double)	16000	0.362	0.218
Sodium bi-carbonate	(single)	3336	0.076	0.054
" "	(double)	6672	0.151	0.109
Sodium carbonate	(single)	4288	0.097	0.054
" "	(double)	8576	0.195	0.109

For calculating the percentage concentrations for one acre-foot of the soil it was taken that a cubic foot of soil weighed 100 lb. and consequently one acre-foot would weigh 4.4 million pounds. These quantities of salts when added to the soil were expected to be washed down by irrigation at least to a depth of four feet. The soil of the field where this experiment was laid out was normal (without salinity). Salts were added behind a deep furrow-turning plough on the 16th to 18th March and the plots were irrigated three times at regular intervals before sowing cotton seeds so that the salts may be washed down to lower layers and should not injure the seedlings. American cotton 4F was sown by the middle of May. Various observations were made and carefully recorded. For detailed results reference to the published paper by Dastur and Sucha Singh (1942) may be made.

Sodium chloride in low concentrations depressed to a small extent the vegetative growth and had no effect on the fruiting parts and yields. The same salts under high concentration were found to exercise a very great depressing effect on its vegetative and fruiting parts. The total dry weight per plant, height per plant, leaf area, yield and boll weight were significantly lowered in the presence of sodium chloride when applied at the rate of 16,000 lb. per acre. The weight of seed cotton per boll was greatly reduced as the seeds remained immature and consequently the chief symptom of *tirak* was reproduced in the presence of sodium chloride.

Sodium carbonate in low concentrations (4,288 lb. per acre) showed some depressing effect on the vegetative growth but it was found to have a small stimulating effect on production of the boll material and consequently the yields. The most noticeable feature was the increase in the boll weight. High concentrations of the same salt (8,576 lb. per acre) depressed greatly the vegetative growth resulting in low dry weights and heights. The yields were lowered as compared with the yields obtained under low concentrations of this salt (Table 29).

Both the salts had decreased the internodal lengths but had no effect on the number of nodes. Sodium bi-carbonate had no effect on the growth of the plant either under low or high concentrations except for an indication of a stimulating effect on the yields.

The effects on the plant development of sodium carbonate and of sodium bi-carbonate were different in the presence of sodium chloride. The depressing effect of carbonates on plant growth increased in the presence of sodium chloride so much so that the dry weights, heights, boll material and yields were greatly reduced under high concentrations of the two salts. The case was different with sodium bi-carbonate where this salt in high concentration appeared to decrease the depressing effects of high concentration of sodium chloride. It was on account of this differential behaviour of the two salts in the presence of chloride, that the interaction quality with chloride was found to be significant on the dry weight, height and boll material.

The sodium chloride depressed both the vegetative growth and yields. It also produced the immaturity of seeds and thus caused 'bad opening'. Carbonate decreased the vegetative growth but had a stimulating effect on fruiting parts in low concentrations. Bi-carbonate in a high concentration appeared to decrease the depressing effect on yield of high concentration of sodium chloride.

The sodium salts found in soils where *tirak* occurred were chloride, bi-carbonate and sulphate of sodium while sodium carbonate was either present in very small amounts or was absent. It appeared from the results discussed above that the disturbance in the presence of sodium chloride was greater than in the presence of sodium bi-carbonate, as in the experiments, no depressing effect on plant growth was visible when the latter salt was applied in

TABLE 29. EFFECT OF SODIUM SALTS ON BOLL NUMBER, BOLL WEIGHT AND YIELD

		Total number of bolls per plant				Weight of seed cotton in gm. per boll				Final yields in gm. per plot (1/186 acre)			
		Con- trol	Sod. Bic.	Sod. Bic.	Sod. Bic.	Mean Con- trol	Sod. Bic.	Sod. Bic.	Sod. Bic.	Mean Con- trol	Sod. Bic.	Sod. Bic.	Sod. Bic.
		I	II	I	II	I	II	I	II	I	II	I	II
Control		34.1	44.4	38.1	37.6	37.6	37.6	37.6	37.6	1.22	0.99	0.99	1.32
Sod. Chloride I		38.2	42.2	42.8	50.3	38.5	41.7	1.02	1.15	1.32	1.35	0.79	1.10
Sod. Chloride II		34.2	34.1	36.0	32.7	32.4	33.9	0.83	0.81	0.96	1.15	1.10	0.95
Mean		35.5	40.2	38.9	40.2	36.2	37.7	1.02	0.98	1.09	1.25	1.07	1.07
Mean boll number		Mean weight of seed cotton per boll in gm.				Mean yield per plot in gm.							
Sod. Chloride	Chl. 0	37.6	41.7	38.1	37.6	37.6	37.6	37.6	37.6	1.16	1.32	1.32	1.16
	Chl. I	37.6	41.7	38.1	37.6	37.6	37.6	37.6	37.6	1.16	1.32	1.32	1.16
Quality	Sod. Bic.	39.5	41.7	38.1	37.6	37.6	37.6	37.6	37.6	1.16	1.32	1.32	1.16
	Sod. Carb.	39.5	41.7	38.1	37.6	37.6	37.6	37.6	37.6	1.16	1.32	1.32	1.16
Quantity	Sod. Bic.	39.5	41.7	38.1	37.6	37.6	37.6	37.6	37.6	1.16	1.32	1.32	1.16
	Sod. Carb.	39.5	41.7	38.1	37.6	37.6	37.6	37.6	37.6	1.16	1.32	1.32	1.16
S.E. = +2.42		S.E. = +0.0937				S.E. = +184.5							

concentration in which it was generally found to be present in such saline soils. It was quite possible that in much higher concentrations than those used here, any of the sodium salts may also produce similar depressing effects on growth. When sodium carbonate was present along with other salts the depressing effect was greatly aggravated. Thus the intensity of *tirak* symptoms would depend on the total concentrations of these salts, their nature and their relative proportions in the soil. It was the combined effect of these salts that produced *tirak* symptoms in natural conditions and it might be modified by other soil conditions like the clay content and soluble calcium salts.

REMEDIAL MEASURES FOR TIRAK

The application of nitrogen in the form of sulphate of ammonia to nitrogen deficient light sandy soils and the application of extra irrigations, either in the form of heavier doses or at shorter intervals than normal, during the fruiting period, were found to be the best remedies for *tirak*. But the chequered nature of the cotton soils did not make possible their use on a practical scale. These remedies are specific and must be applied at the right places. Application of nitrogen in the form of sulphate of ammonia to soils with sub-soil salinity would not prove a remedy. Similarly, the application of extra water to nitrogen deficient soils would have no effect. The soil heterogeneity and the two different physiological factors associated with *tirak* involving application of two different remedial measures, stood in the way of remedying it on a practical scale.

It was, therefore, necessary that the remedial measures should be such that they would ameliorate *tirak* occurring on account of nitrogen starvation and of water starvation. The measure should also be such that they would not adversely affect the growth of the crop on normal lands. .

The damage caused by *tirak* can be reduced by ensuring that the crop does not suffer from a deficiency of either nitrogen or water or both at the time of fruiting. A reduction in plant size was, therefore, conceived to be the most natural way. The only way to reduce plant size seemed to lie in shortening the vegetative growth period by delaying the sowing of the plant for a period to be determined experimentally.

Cotton sowings in the Punjab generally began in the first week of May. The effect of June sowing on the plant size and consequently on *tirak* on both the soil types was, therefore, studied experimentally. This measure proved extremely successful in the first year of its trial. A field having saline sub-soil was divided into 48 equal plots of which half were sown at random in May and half in June. *Tirak* appeared in the May-sown plots while the plots sown in June were found to be almost free.

The measure of late sowing was, therefore, tried out in the succeeding years on the soils where nitrogen deficiency caused *tirak* and also where both

tirak-promoting conditions were found to be present together, i.e., on light sandy soils with saline sub-soils. The measure was also tested in the various cotton growing districts of the Punjab using the commonly cultivated American varieties. In all 38 trials were conducted. The net result of these trials was that the crop sown in June suffered much less than the crop sown in May. Late sowing was found to be a common measure suitable for all soil types. The practical difficulties arising out of the soil heterogeneity were thus surmounted.

The June-sown crop, however, suffered from one serious disadvantage as compared with the May-sown. As the vegetative growth was shortened by delay in sowing, it produced a smaller number of bolls per plant. Thus *tirak* could be ameliorated but the advantage gained by better opening was lost by a decrease in bearing. This disadvantage was counteracted by closer spacing of plants, i.e., by increasing the number of plants per acre. Cotton plants in the Punjab were generally sown in rows 3 feet apart. The plant to plant distance was generally $1\frac{1}{2}$ feet. The reduction in boll number per plant caused by June sowing was avoided by spacing the rows at $2\frac{1}{2}$, 2 and $1\frac{1}{2}$ feet successively as the sowing date advanced. Similarly, the plant to plant distance was decreased from $1\frac{1}{2}'$ to $1\frac{1}{4}'$, $1'$ and to $9'$ as the sowing date advanced in the month of June. The importance of steadily increased closer spacing of plants with the advancing sowing date was demonstrated by number of experiments. It was found that great increases in the yields were obtained by adopting June sowing with close spacing (Plate IVb).

The May-sown crop was, therefore, not in equilibrium with its edaphic and climatic environment on such saline soils. In years favourable for the growth of the crop these symptoms developed on small areas where salinity was very high in the sub-soil but any weather factor that increased the water loss from the crop led to the intensification and spread of this trouble on extensive areas resulting in great losses in yield. *Tirak* was, therefore, a cause of physiological maladjustment at the fruiting stage (Plate IVa).

The chief difficulty in understanding the cause of *tirak* and its wide spread occurrence in certain years lay in the extreme heterogeneity of the Punjab soils. The premature defoliation of the crop and the immaturity of seeds were caused under two different soil conditions which are usually found intermingled. The soil heterogeneity thus rendered both observation and experiment difficult. A field produced *tirak* crop in one season but it bore normal crop in the next season. Pure soil studies even if they were attempted would have yielded no information unless they were accompanied by a study of the crop in its physiological and chemical aspects.

The importance of this measure against *tirak* was in its general applicability. It was found efficacious on all soil types as it put the crop in equilibrium with its surroundings. The June sowings were found to be better adapted to its environment than the May sowings. This was true of

even normal soil where *tirak*-promoting conditions did not exist. The plants were able to carry on their normal functions with less nitrogen and less water and the deficiency of these substances did not develop. The plants were also better able to stand the adverse weather conditions at the fruiting stage and thus general intensification and spread of *tirak* were greatly lessened. The internal economy of the plant greatly improved and the plant produced less of sticks and more of fruits. The efficiency of the plant for producing seed cotton rose from maximum of 20 per cent. in the May-sown crop to nearly 50 per cent. in the June-sown crop. It produced more seed cotton in proportion to its size. The May-sown crop exhausted itself in producing vegetative growth and reached a state of senescence when the bolls began to form. It was, therefore, not able to stand the vagaries of weather which is many a time dry and warm during the fruiting period. The June-sown crop being comparatively young was able to adjust itself to such abnormal fluctuations in its aerial environment.

This simple measure of differring sowings by about three to four weeks, i.e., from the first week of May to last week of May has been found to result in great profits to cotton growers and many of them have already benefited.

The cotton crop at the Farm of the British Cotton Growers' Association, Khanewal, was frequently subject to intense *tirak* and the yields were generally much below expectation in spite of a high standard of cultivation. The crop was found by the senior author to suffer from *tirak* in 1937, 1938, and especially in 1939 when the crop had completely failed. The cotton sowings on this farm used to start from the first May and were completed by the beginning of June. Thus 90 per cent. of the total acreage under cotton was planted in the month of May. The annual acreage under the crop was about 1,600 to 2,000 acres. In 1940, the cotton sowings were shifted to the month of June and the crop was planted closer and closer with each advancing week in June. This practice has since been continued. During the last few years the cotton sowings were completed within the first three weeks of June to avoid damage caused by jassids in a jassid-year, like 1944, which proved to be the worst jassid-year in the history of the American cottons in the Punjab.

During these 16 years of the adoption of this improved practice of cotton sowings the crop had not suffered to any appreciable extent from this disease even though 1941 and 1946 were partial *tirak* years on account of unusually hot and dry weather during the fruiting period. The cotton yields of the farm, even in these two years, were normal.

In order to get an approximate idea of the benefit derived by the British Cotton Growers' Association Farm during these 16 years on account of late sowings, the average yields per acre for the last 17 years 1940 to 1956 were compared with the average yields per acre for the previous 16 years 1924 to 1939 when the cotton sowings were done in the month of May at 3 feet distance.

The period of 16 years was regarded sufficiently long for such an estimate of benefit as the seasonal effects on the yield may be expected to average out during this period.

It was clear that the average yield of seed cotton per acre had increased by about two maunds (164 lb.) during the last 16 years of late sowings with closer spacings. Taking the average price for seed cotton during these years at Rs. 30 per maund, this farm derived annually an extra benefit of Rs. 1,08,000 from an average of 1,800 acres under cotton.

The same measure of late sowings by two to three weeks in different parts of Sind proved successful in ameliorating the 'bad opening' of bolls in Sind-American cottons, as the same two soil types were again found to be associated with the 'bad opening' of bolls in Sind-American cottons.

SOIL TEMPERATURE INTERACTION IN RELATION TO TIRAK

It was pointed out that the degree of salinity varied and, therefore, the extent of water deficiency produced in the plant would also vary. There were soils which had low salinity and the plants did not suffer from *tirak* under normal conditions of irrigation and under favourable conditions of weather. If by chance an irrigation was delayed or was missed at the fruiting stage the cotton crop in such fields would develop *tirak*. If the weather conditions during the months of September and October were warm and dry continuously for a number of days they promoted a greater water loss than was usually the case and the equilibrium between demand and supply of water was disturbed.

It was noticed that *tirak* developed in such lands under such unfavourable weather conditions, while it was not seen on the same land under normal conditions of irrigation and under favourable weather conditions. Weather conditions were thus responsible for a great intensity of *tirak* and its wider spread than normal on this type of soil, in certain years, which were called years of cotton failures. A continuous spell of drier and warmer weather in September and October lasting for two to three weeks or more will upset the water relations of plants with soils with saline sub-soils and *tirak* was intensified in such seasons. Such weather would also cause spread of *tirak* on soils with low salinity in the sub-soil. Thus larger areas than the normal showed *tirak*-affected crop in such years of unfavourable weather conditions.

The correlation studies between the temperature and yields of cotton in the Punjab have produced some definite results. *Tirak* was known to depress the yields. The causes of *tirak*, the stage at which the symptoms developed and the interaction of soil salinity with temperature on development of *tirak* also became known. So only the weather factors at the fruiting stage which aggravated the condition of physiological drought had to be studied. The maximum temperature was found to be the important factor but the variations in yield were, however, not found to be correlated with

variations in monthly temperatures. Recourse was, therefore, taken to an arbitrary method of selecting such spells of hot weather in the two fruiting months when the temperature rose above the normal monthly mean maximum temperature. For this study the average yields for three important districts and three big cotton farms for the 20 years were taken and correlation coefficients between the yield and spells of higher maximum temperature than normal in September and October were taken. The results (Table 30) indicated one common feature; the values of correlation coefficients were negative in all cases. Thus a definite negative correlation between the degrees above the normal monthly mean of maximum temperature, in a spell of eight days or more, and yields became evident even though in some cases the value of correlation coefficient did not reach the level of significance. Though this method of taking the temperatures of the spells may be considered arbitrary it is quite sound from a physiological point of view as the greatest disturbance in the metabolic activities of the plant would be caused during the hot spells irrespective of the fortnightly or the monthly means.

TABLE 30. CORRELATION COEFFICIENT BETWEEN YIELD AND SPELLS OF HIGH MAXIMUM TEMPERATURES IN SEPTEMBER—OCTOBER, 1921-1940

Place	Time trends not eliminated	Time trends eliminated	Time trends not elimi- nated	Time trends eliminated
	Americans		Americans + Desi	
Lyalpur	-0.4493	-0.1036	-0.2635	-0.2655
Montgomery	-0.4776*	-0.4105	-0.3266	-0.4126**
Multan	-0.7211**	-0.4088	-0.5776**	-0.5566**
Burcepur Farm	-0.1155	-0.2256	—	—
Okara Farm	-0.4958*	-0.4535	—	—
B.C.G.A. Farm	-0.5616*	-0.3985	—	—

RED LEAF DISEASE IN HIRSUTUM COTTONS

PUNJAB AND SIND COTTONS

The reddening of leaves in American cottons has been reported to occur ever since this type of cotton was introduced in India. Burt and Haider (1919) reported this phenomenon in Cawnpore-American cottons in United Provinces, and later the same disease was reported by Kottur (1920) from Dharwar and by Prayag (1927-28) from Khandesh. The reddening of leaves was also found to occur in the Punjab during the years when cotton crop failed in that Province (Milne, 1921, 1922). It was found to be present, by Sawhney (1932), in Hyderabad Deccan. The red leaf disease was also of common occurrence in Sind (Dabral, 1938). It was also found to occur in the American Upland cottons grown in Central India (Rao and Wad, 1936). Thus it was a disease appearing in all parts of India where American cottons were grown.

As the red leaf in *hirsutum* cottons has been reported to occur under different conditions of soil and climate, the causes that give risk to this common symptom in the leaves may be different. It was, therefore, necessary to determine the different conditions under which this disease occurs.

The red pigment in the leaves of *hirsutum* cottons is also found to develop as a result of injury caused by jassids (Sawhney, 1932). The injury causes the death of leaf tissues and the red pigment subsequently develops. The present investigation describes the red leaf that occurs in the absence of jassid injury.

Rao and Wad (1936) have concluded that this disease was caused by the bad soil conditions during the monsoon period in Malwa tract. They have also reported a higher osmotic pressure of the soil solution surrounding the diseased plants as compared with the osmotic pressure of the soil solutions surrounding the healthy plants. Numerous determinations of the soluble solids in the soils from near the diseased and healthy plants revealed no differences that could account for such wide differences in the osmotic pressure.

Dabral (1938) had differentiated the red leaf disease into different types of which one was caused by a deficiency of nitrogen and this was cured by the application of various fertilizers containing nitrogen. It was later found that yellowing and not reddening was a symptom of nitrogen deficiency, and that reddening was an after-effect that followed yellowing. In many cases reddening after yellowing did not occur. It was later shown (Dastur, 1939, 1941) that yellowing of leaves that occurred in the Punjab-American cottons in the Punjab was caused by a deficiency of nitrogen in light sandy soils where the development of the red pigment was not found to be of general occurrence.

The red leaf disease was, therefore, investigated in four different tracts, namely : (i) the West Punjab ; (ii) Sind ; (iii) Central India ; and (iv) Bombay-Karnatak. In the first two tracts it was found to be caused by an insufficiency of nitrogen on light sandy soils. The leaves of the plants which showed this type of reddening during the fruiting phase contained significantly less concentration of nitrogen than the leaves of the plants which remained green in colour. Some varieties of cotton like M.4 in Sind which were found to be less affected by the yellow-red leaf were found to contain a higher concentration of nitrogen than those varieties like Sind Sudhar which showed these symptoms in a pronounced degree (Table 31). If these cottons were manured with sulphate of ammonia the yellow-red leaf did not appear. The analysis of the leaves indicated a higher concentration of nitrogen in such cases. Similarly, the crops sown late did not suffer from this disease as the concentration of nitrogen was not reduced to a critical level. The critical concentration of nitrogen when these symptoms developed appeared to be below two per cent. (Dastur and Kanwar Singh, 1947).

TABLE. 31 MEAN PERCENTAGE OF NITROGEN IN LEAVES ON DIFFERENT DATES AT HYDERABAD (SIND)

Variety	23rd July	7th Aug.	23rd Aug.	7th Sept.	23rd Sept.
<i>Date of Sampling</i>					
M.4	3.47	3.14	2.66	2.31	1.79
Sind Sudhar	3.19	2.91	2.46	2.07	1.64
L.S.S.	2.96	2.70	2.50	1.87	1.47
S.E. \pm	0.028	0.020	0.022	0.022	0.031
<i>Nitrogen</i>					
Manured	3.39	3.03	2.78	2.28	1.70
Control	3.02	2.80	2.29	1.88	1.56
S.E. \pm	0.035	0.034	0.043	0.029	0.034
<i>Sowing Date</i>					
Latesowing	3.49	3.18	2.85	2.38	1.79
Early sowing	2.92	2.65	2.22	1.78	1.47
S.E. \pm	0.035	0.034	0.034	0.029	0.034

The application of sulphate of ammonia also significantly increased the yield.

The trouble was found to be more wide-spread in the southern tracts of Sind than in the Punjab. In fact it was noticed almost in every season in Sind. The causes of such frequent occurrence of yellow-red leaf were investigated and it was found that in addition to the soil factor, viz., sandy nature of the soil, the climatic conditions in South Sind caused the wide-spread occurrence of this trouble. The higher night temperatures during the fruiting period in Sind caused a more rapid maturation of bolls. A large number of determinations indicated that the maturation period of bolls varied from 33 to 39 days. The crop finished off in two months, i.e., in September-October. In the Punjab, there was late initiation of flowering in September on account of very high temperatures in July and August and the fruiting period, therefore, coincided with the falling night temperatures in October, November and December. The maturation period of bolls was found to vary from 45 to 70 days. The crop finished off at the end of December or the beginning of January.

The rapid maturation of the crop in South Sind caused heavy depletion of nitrogen from the leaves which consequently became senescent, turned yellow and red. Thus the red leaf trouble was accentuated and it spread to lands where normally this disease did not appear under middle Sind and the Punjab conditions.

AMERICAN UPLANDS IN MALWA

Observations made on the appearance of the red leaf in American Upland cottons grown in Malwa indicated that the reddening also occurred in this tract at the fruiting stage, i.e., in October-November. It is the stage

when the demand for elaborated food materials was high and consequently the leaves rapidly began to be depleted of food materials bringing about their senescence. It was invariably observed that the plots that had received a dressing of sulphate of ammonia were the first to show the leaf reddening. The reddening in the ammonium sulphate plots appeared two to three weeks earlier than the control plots. Thus application of sulphate of ammonia hastened reddening instead of delaying it as was found to be the case in the Punjab and Sind.

The early reddening of the crop in the manured plots was also found to be associated with an early maturity. The plots that received the sulphate of ammonia matured earlier by 10 to 15 days than the plants in the unmanured plots. This fact of early maturity in the manured plots was varified by determining the index of earliness by using Bartlett's formula in a factorial experiment comprising of four levels of nitrogen, three levels of potash and three levels of phosphoric acid. The index of earliness for each level of nitrogen is given below (Table 32). The higher value of index indicated comparatively early maturity.

TABLE 32. EARLINESS INDEX IN MATURITY UNDER DIFFERENT DOSES OF NITROGEN

	Control	25 lb. N	50 lb. N	75 lb. N	S.E.
Earliness index	0.63	0.68	0.72	0.71	± 0.006
Per cent. of first picking to total	49.4	58.8	61.1	60.8	± 0.73

The crop matured earlier in the manured plots by about 10 per cent. and a higher dose than 50 lb. nitrogen did not further make the crop early.

It was thus clear that early maturity brought about an early senescence of the leaves. Thus both the facts, viz., appearance of the red leaf at the crop maturation stage and hastening of maturity and consequently of early reddening, by manuring suggested depletion of food materials from the leaves which became senescent. It is at this stage that the temperatures drop in Malwa below 70°F. and this drop in temperature was known to be favourable for the formation of anthocyanin pigments.

The application of sulphate of ammonia was also found to hasten maturity in the case of *arboreum* cottons grown at Indore and *herbaceum* cottons at Surat. But the leaves of these cottons did now show reddening as in the case of *hirsutum* types.

In order to confirm experimentally that the reddening of leaves was related to maturation of the crop in the black cotton soils under rainfed conditions, it was undertaken to study the effect on leaf reddening by extending the period of maturity by artificial means. This object was attained by weekly removal of the buds and flowers from the time of their appearance.

The crop was thus maintained in the vegetative stage. The debudding of 10 plants under each treatment was started from the 20th August in the control as well as in the plots treated with sulphate of ammonia and ammonium phosphate while 10 plants were allowed to fruit normally in all the three treatments. Indore 1 was the variety used. The plants in which fruiting was allowed to occur, leaf reddening started in November and manured plants began to show reddening a fortnight earlier. Leaf reddening did not occur (except in the case of very old leaves), in the debudded plants, until the end of the season in all the three treatments. The tops remained green in colour as the bolls were not produced and consequently the leaves did not get depleted of food materials.

This experiment was again repeated in the next season on a larger scale and the above-mentioned observations and conclusions were confirmed.

It was also found later that when Indore cottons were grown at Gadag (Bombay-Karnatak), they showed Gadag type of leaf reddening which appeared early at the stage of bud formation and which became less and less as the crop matured. Similarly, when the Gadag cottons were grown at Indore, they showed Indore type of leaf reddening. A quantitative method of measuring the red leaf blight index was worked out and all the conclusions discussed above were tested (Dastur, Kanwar Singh and Kaiwar, 1952). From another experiment comprising of all the combinations of three varieties (Indore 1, Gadag 1 and Laxmi), two levels of nitrogen (0 and 50 lb.) and two treatments (control and debudding) at Indore the following conclusions were arrived at.

The red leaf blight appeared towards the end of October, i.e., at the fruiting stage, in all varieties. Thus Gadag cottons also showed Indore type of the red leaf. Laxmi suffered significantly less from the red leaf than Indore 1. Laxmi was known to be a red leaf-resistant variety. The red leaf blight also increased as the season advanced in the case of all varieties.

Manuring with sulphate of ammonia significantly increased the reddening of leaves in all varieties. The manured plants showed leaf reddening a fortnight earlier than unmanured plants. The red leaf index was significantly less in the defruited plants than in the control plants.

This type of red leaf did not appear to affect adversely the yields as it appears late in the season when the crop is maturing. The only reason for such a conclusion is the effect produced by sulphate of ammonia on the leaf reddening and yield. Though the red leaf appeared a fortnight earlier in the manured plots, the yields of seed cotton increased as compared with the yields in the control plots where leaf reddening occurred at a later stage.

DHARWAR-AMERICAN COTTON

The Dharwar-American cottons in Bombay-Karnatak are known to suffer from the red leaf blight ever since their introduction in that tract.

The crop is planted towards the end of September and the reddening appears towards the end of November. The observations made on the crop showed that the red leaf that appeared in this tract developed on account of different causes than those that were responsible for the red leaf type studied in Malwa.

In order to confirm this view the effect of the same two measures, viz., manuring and debudding was studied at the Agricultural Farm at Gadag. These two physiological tests would reveal if the reddening that occurred in this tract was produced by the same causes as in Malwa or the causes that operated in producing this phenomenon were different.

The application of sulphate of ammonia did not show any difference in the appearance of the red leaf in the control and manured plots. It appeared in all plots at the same time. This was confirmed by the results of the red leaf index determinations. There was also no effect of manuring on the time of the appearance of the leaf reddening while the manured plots at Indore had shown an early onset of reddening. The intensity of reddening at Gadag was slightly less in the manured plots than in the unmanured plots though the differences between the red leaf blight index in the manured and unmanured plots were not significant. This was not the case at Indore where the red leaf index in the manured plots was significantly higher than that of the unmanured plots. Thus manuring had not produced the same effect on the leaf reddening at Gadag as it had done at Indore.

The leaf reddening was again significantly less in Laxmi than in Gadag 1. Similarly manuring had no effect on the maturity of the crop at Gadag. This was another difference between the two tracts on the effects produced by manuring. The crop arrival was almost the same in the manured and unmanured plots at Gadag.

The effect of debudding was also studied at Gadag and it was found that leaf reddening occurred in all the treatments where debudding was done. There was thus no effect of weekly removal of buds in preventing leaf reddening at Gadag. The results obtained at Gadag were, therefore, different from those obtained at Indore. The leaf reddening started in November in all treatments. Thus all the physiological tests gave different results at Gadag and Indore.

In view of the different effects of manuring and debudding obtained at Indore and Gadag it was necessary to determine if they were due to varietal difference. An experiment laid out at Gadag using three varieties; Indore 1, Gadag 1 and Laxmi and two treatments, control and debudding showed that there was no difference in the red leaf blight index between control and debudded plants. The leaf reddening was most intense during November and December after which there was a decline in the red leaf blight index. That may be due to the production of new leaves which were not affected by the red leaf blight and the shedding of older leaves. Indore 1 suffered from the red leaf blight in the same manner as Gadag 1 and Laxmi. Indore 1

thus behaved as Gadag varieties and showed the Gadag type of the red leaf when grown in that tract.

The results of the red leaf blight index for the 28th November were statistically analysed as the value for the index was highest on that date. It was found that the red leaf index was significantly higher in Gadag 1 than in Indore 1 while it was significantly less in Laxmi than in Indore 1.

As the red leaf blight appeared at the fruiting stage at Indore, nutritional factors were partly responsible for it while at Gadag environmental factors appeared to produce the red leaf blight.

During the senior author's visit to the fields in the cotton season of 1946-47 it was evident that east-north-easterly winds that blow in the months of November to January had a desiccating effect on the leaves especially on the margins. The margins had turned brittle and brown and in some cases the red pigments were present on such dead parts. The wind caused the loss of water from the leaves and the tissues at the margins, and the apex became functionless. The red patches appeared more and more as the season advanced and as the night temperatures dropped. Thus the internal conditions for the development of the red leaf were first produced. It was also found that the red pigments developed in such dead parts while the development of the red pigment did not occur in other similar parts. The easterly wind generally ceased in the latter half of January and further damage to the leaves was not found to occur. The newly formed leaves thus appeared to escape injury caused by desiccating winds. As the older leaves were shed the red leaf blight appeared less and less.

The wind velocity and minimum temperatures were studied for the years 1948-49 to 1950-51 when the red leaf blight index was determined for the different strains of cotton. The wind velocity during the day was most important as it would greatly increase the rate of transpiration from the leaves during the hot hours of the day. So the monthly averages of the wind velocity at 11.30 a.m. and at 5.00 p.m. were studied for the months of October to January for the three years. The direction of the wind was generally ENE or NE in almost all the days in November-December and a part of January. On a few days the direction of wind was ESE. The wind velocity is more important than its direction as its desiccating influence would remain the same irrespective of the direction.

The monthly means of minimum temperatures were also obtained for the same months as lower temperatures were known to be associated with the development of the red pigments. In some years the injury to the leaves may be extensive on account of the high wind velocity but the red pigments may not develop to a great extent if the minimum temperatures were high. *Vice versa* may be the case in other years. The injury may be less but the red pigments may develop on all injured plants if the temperatures in these months fell much below the general average.

In 1950 season, the red leaf blight was more severe than in other two years and a study of the weather data revealed that both the factors were present in optimum for the development of the red pigment. The wind velocity in November and December was fairly high and the minimum temperatures were abnormal for that tract from the month of October to December. Thus the red leaf blight was observed to be more severe in that year (Table 33).

TABLE 33. RELATION BETWEEN RED LEAF BLIGHT AND WIND VELOCITY AND MINIMUM TEMPERATURE

Period	Wind velocity (M.P.H.)		Monthly mean of minimum temperature °F	Red leaf blight index in Laxmi
1948-49	11.30 a.m.	5.00 p.m.		
October	2.45	3.16	74.9	Nil
November	2.40	3.33	72.9	0.12
December	3.70	3.29	68.9	0.08
January—1949	3.70	3.20	64.1	0.20
1949-50				
October	4.61	4.87	73.0	Nil
November	9.70	7.30	73.1	0.017
December	9.01	6.29	72.8	0.050
January—1950	2.00	2.00	60.5	0.017
1950-51				
October	4.39	3.48	64.5	Nil
November	7.87	3.23	61.0	0.20
December	8.35	5.45	57.0	0.32
January—1951	1.80	0.07	—	—

The red leaf blight should have been still more severe in 1949-50 than in 1950-51 as the wind velocity for the same months was higher than in 1950 season but the development of the red pigment did not occur to the same extent as the minimum temperatures were high during these months. They were 73°F. in 1949 as compared with 61°F. and 57°F. in 1950.

The wind velocity was low in 1948 season and the temperatures were not low. The incidence of the red leaf blight was reported to be medium in that year.

The above are general inferences regarding the variation in the red leaf blight from season to season. There must be other internal factors such as accumulation of the products of photosynthesis and the formation of chromogens which give rise to red pigments. They all play their part in relation to the external factors discussed above. It is, however, definitely known that mechanical injury causes the development of the red pigment and the lowering of temperature is also known to be related to its development. The extent of reddening would also depend on the variety or the strain of cotton.

It is not known if the development of the red pigment in the leaves at Gadag was associated with the lowering of the yield of seed cotton per acre

under Gadag conditions. As the wind velocity has a desiccating influence on the leaves the photosynthetic activity of the crop must be considerably lowered during that period. Consequently the general growth of the crop is expected to be affected adversely.

It is a matter for investigation if the yields of seed cotton can be increased by providing protection to the crop in the form of wind screens of some tall crop plants or trees surrounding the cotton fields at Gadag. Direct experimental evidence can also be obtained regarding the suggested causes that produce the red leaf blight at Gadag by working under controlled conditions of wind velocity and temperature.

PHYSIOLOGICAL CAUSES OF LOW YIELDS

PUNJAB

Attempts have been made in the past by the cotton breeders to grow and to acclimatise the long stapled Egyptian and Sea Island cottons in the north-western tracts of India but they met with no success. Experiments were conducted in Sind before the opening of the Sukkur Barrage to acclimatise these cottons as the climatic conditions in Sind were regarded similar to those prevailing in Egypt. Seeds were imported from Egypt and West Indies and they were able, by proper selection, to evolve two strains, Boss III-16 and Sea Island 2-4 with staple length of 1-1 8" to 1-1 12". Previous records collected from the Agricultural Farm at Oderolal in Hyderabad district (Sind) showed that the yields of these cottons varied from 6 to 12 maunds (one maund=82-2/7 lb.) per acre in the varietal trials conducted from 1934 to 1936. The seeds were also distributed to private cultivators and at one time the acreage under these cottons was reported to be 1,200 acres. But they went out of cultivation on account of reasons that cannot be correctly ascertained now. These cottons were reported to be very susceptible to white ant attacks which so reduced the cotton stand that very low yields per acre were obtained. It is also possible, though by no means certain, that the seeds were impure as they may have contained the seeds of hybrids between Egyptian and Americans and the level of yield per acre was perhaps raised on account of the presence of these hybrids which produce normal crop of bolls. No success was achieved in the Punjab also in introducing these cottons in that tract and they were found unsuitable. The yields were very low even though they made very good vegetative growth.

When the seeds of Sind Sea Island cotton were obtained from Sind and planted in the Punjab in May, it was found that though the vegetative growth was normal, flowering and fruiting were meagre. The leaves were found to be heavily infested with jassids. As the vegetative growth was normal and the fruiting very poor in the crops sown in May a sowing date experiment was conducted in the Punjab to study the effect of the five different

sowing dates beginning with the 28th March, with an interval of 20 days, on the growth and bearing of these cottons. It was found that March and April sowings produced a very vigorous vegetative growth and the growth then declined as the sowing date advanced. The height per plant, bearing and yield declined as the sowings were done later, so much so that the crop sown on the 18th June and the 10th July did not give any yield.

It may be stated that very high yields of 11 maunds per acre obtained in the first three sowings were due to the presence of vigorous hybrid plants and these figures, therefore, did not represent the true yields of *barbadense* cottons. In a similar trial conducted at Lyallpur, the yields obtained ranged from three to four maunds per acre even in the early sowings.

The most noticeable feature of these cottons grown in the Punjab was that though these plants produced about 200 to 280 gm. of dry matter per plant and attained a height of 150 to 175 cm. they possessed small bolls containing about 1.15 to 1.5 gm. of *kapas* per boll. The number of seeds per boll varied from 9 to 15. In Egypt these plants were much smaller in size but bore bigger and larger number of bolls.

These plants were ratooned after a study was made of the external characters of the leaves, boll size, seed and lint in the first year. The ratooned plants began to produce leaves in the month of March and by the middle of April the plants were covered with foliage. The first flowers appeared in the second week of May and the rate of flowering increased and reached its maximum in the second week of June after which the flowering declined. The flowering activity almost ceased in the month of July. A second flowering phase set in towards the end of July (Fig. 16) and reached its maximum towards the end of September. The second maximum was much higher than the first one. Flowering activity ceased by the middle of October. It

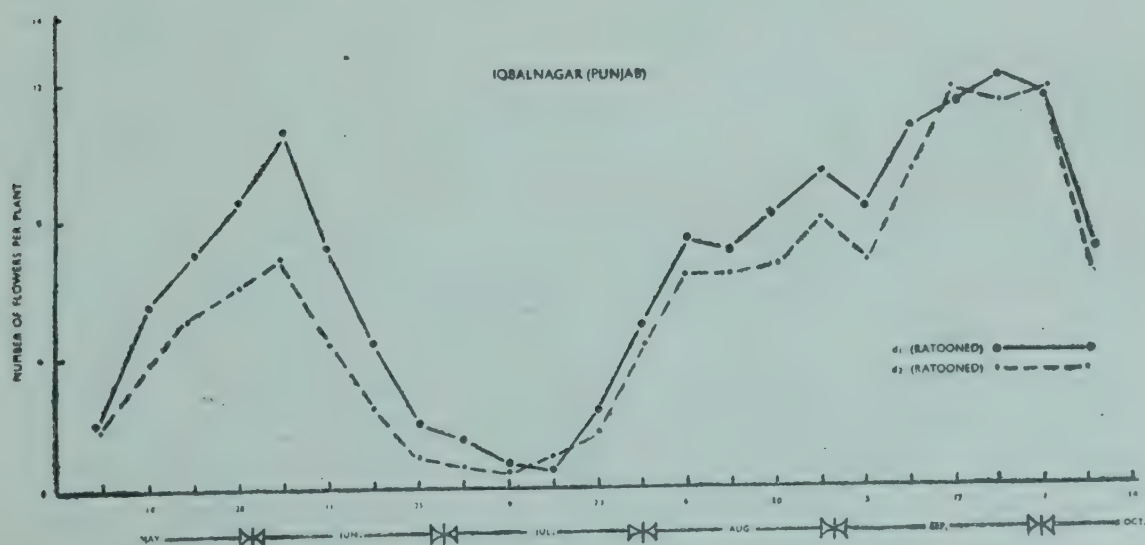


Fig. 16. Flowering Curve for Sind Sea Island Cotton in the Punjab

appeared that very high temperature in the latter half of June and July prevented the development of the fruiting branches which again began to be formed in August when the temperature dropped. If the temperature had been favourable these cottons would have produced flowers and fruits in the Punjab in the same months as in Egypt.

The early formed flowers were mostly shed. The setting percentage was low varying from 16 to 24. The total number of bolls produced per plant was 18.7 and the weight of *kapas* per boll was about 1 gm. The weight of *kapas* per boll increased as the temperature dropped. Similarly, the maturation period of the bolls also increased as the season advanced. There was no difference in the setting percentage of flowers into bolls for the different months indicating that it was not influenced by temperature. The boll weight also increased in those bolls that were produced later in the season.

When the seeds of these cottons were planted in August, as in the Sudan, the plants did not grow at all after poor germination. The study of the relative growth rate and net assimilation rate of these cottons grown under the Punjab conditions gave some indications regarding the physiological causes that appeared to be associated with the low yields of these cottons.

The relative growth rate and net assimilation rate of these cottons as determined in the Punjab and as given by Crowther (1944) for Egypt are given in Figures 17 and 18. The time of the initiation of the flowering phase at the two places is also indicated in the graph. It will be seen that in the Punjab the real reproductive phase set in when both the relative growth rate and net assimilation rate were very low while in Egypt they were quite high at the time of the initiation of the reproductive phase in May-June. Thus the flowering and fruiting occurred in Egypt when the assimilating activities of the plants were high and this may be due to the concurrence of the favourable temperature conditions along with the internal factors. It has been pointed out above that some flowers were also produced in the months of June and July in the Punjab but temperature at that stage in the Punjab was too high for the full development of the reproductive phase which appeared to be suppressed. When the temperature dropped, the flowering phase set in, in the month of August, but by that time the assimilatory activities of the plant became low and consequently fruiting was poor and the bolls remained small containing a smaller quantity of seed cotton. Thus these cottons when grown in March-April in the Punjab, could not mature the crop at a period in its life cycle when its functional activities were high. If the temperatures were favourable when the first indications of the setting in of the flowering phase in the month of June were given, normal yields would have been obtained in the Punjab also. But it missed the time when it was functionally active from a physiological point of view to mature a crop.

As the temperatures were high in the months of June and July (Fig. 19) the development of the reproductive phase was suppressed and consequently

RELATIVE GROWTH RATE

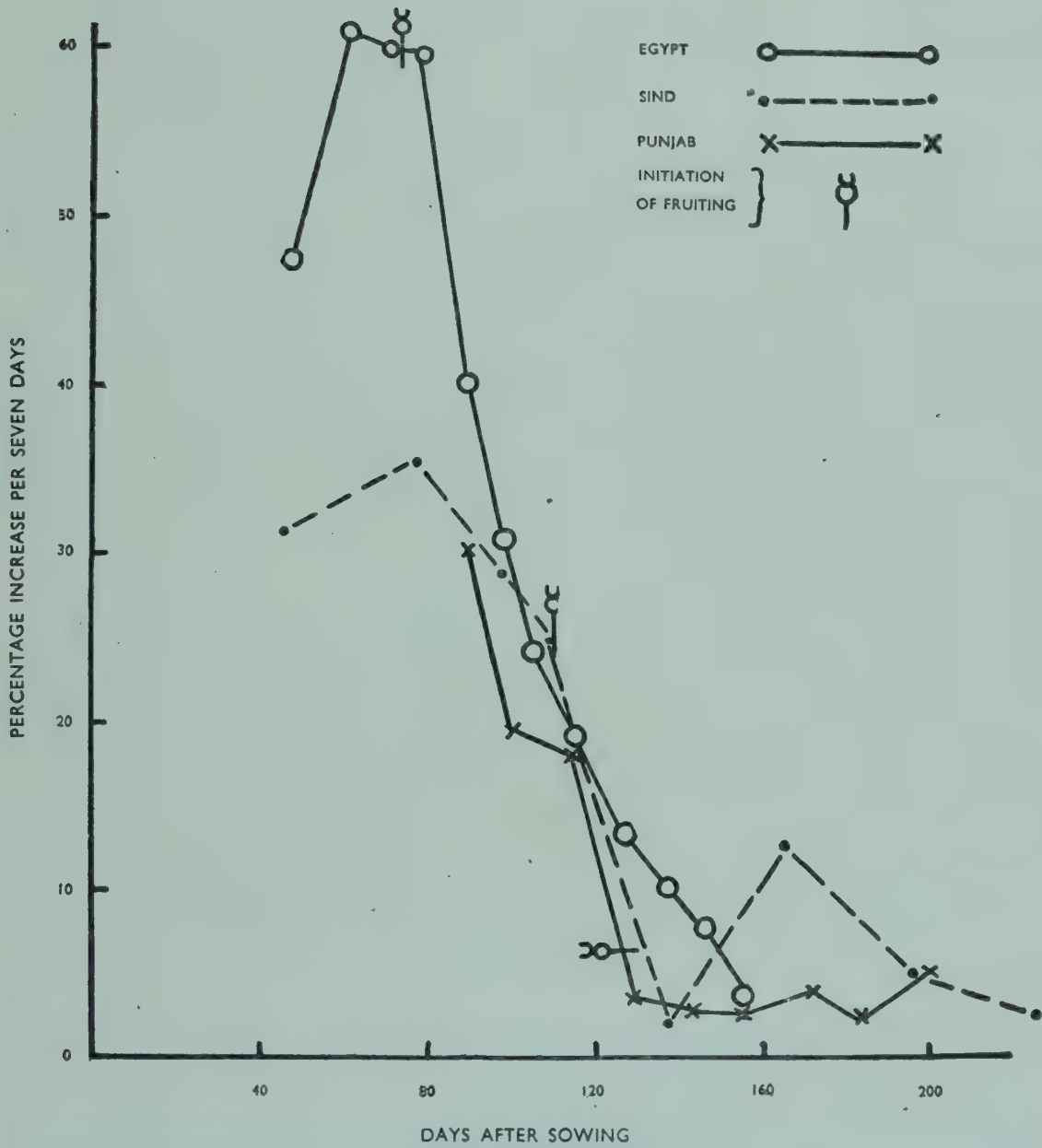


Fig. 17. Relative Growth Rate for Sind Sea Island and Egyptian Cottons

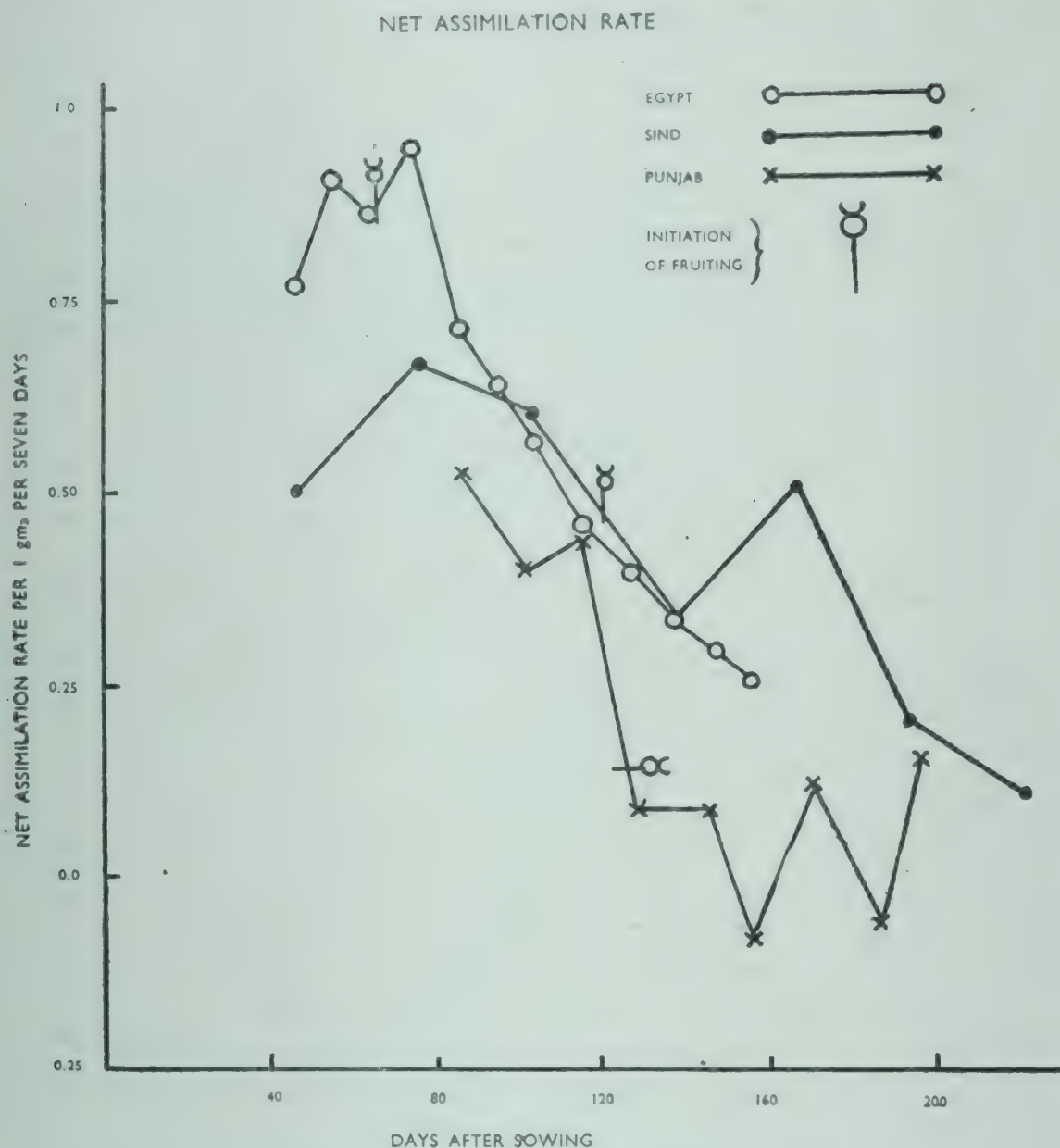


Fig. 18. Net Assimilation Rate for Sind Sea Island and Egyptian Cottons

vigorous vegetative growth occurred instead. Thus the carbohydrates and proteins that would have been normally utilised for the development of bolls were utilised for the growth of vegetative structure. When the reproductive phase set in, in the month of August, the elaborated food materials were available in inadequate amounts for the full expression of the reproductive phase. This conclusion was also supported by the total nitrogen concentrations of the leaves.

The concentration of nitrogen in the leaves of Egyptian cottons in Egypt at the time of the initiation of flowering was 4.6 per cent. of the dry matter. The same concentration of nitrogen occurred in the leaves of the same cotton

in the Sudan. The concentration gradually decreased as the fruits developed and matured and it was 2.4 per cent. at the end of the picking season. The concentration of the nitrogen in the leaves of these cottons in the Punjab was 2.68 per cent. when the flowering phase set in, in the month of August, and it fluctuated between 2.6 per cent. and 2.4 per cent. during the fruiting period. Thus the concentration of nitrogen appeared to be also low for the full maturation of the crop in the Punjab. The low concentration of nitrogen may be an effect of a profused vegetative structure or may be due to a low nitrogen status of the Punjab soils. The latter may not be the case as the application of nitrogen did not increase the yields.

It may, however, be of interest to note that the percentage of nitrogen in the leaves of American cotton in the Punjab was nearly the same as that found in *barbadense* cottons in the Punjab and the former was able to mature its crop normally with that concentration in the leaves. It is not possible in the present state of our knowledge to explain this difference between the two species of cotton but a physiological difference between American and Egyptian cottons was clearly indicated.

SIND

The curves for the relative growth rate and the net assimilation rate for these cottons grown in Sind (Figs. 17 and 18) indicated that the relative growth rate as well as the net assimilation rate were slightly higher during fruiting phase in Sind than in the Punjab.

Though the flowering started as early as the first week of July in Sind the early formed flowers did not either set or the set bolls were shed. The flowering was continuous and did not show any lag period as in the Punjab, where flowering appeared to cease in the month of July. The flowering reached its peak in the third week of August after which the flowering rapidly declined. A small rise in the flowering was noticed towards the end of the flowering season.

As the temperature in Sind dropped from the month of July (Fig. 19) onwards the formation of the fruiting branches continued. It was not suppressed as was the case in the Punjab on account of the prevailing high temperatures there in the month of July. Thus flowering in Sind coincided with a period when the assimilatory activities of the crop were higher than what was the case in the Punjab. Consequently, the fruiting was better and the yields were higher. The conditions in South Sind appeared to be more suitable for the growth of these cottons than the climatic condition in the Punjab; but this difference was of a small magnitude and did not make possible their cultivation profitable on a commercial scale. Still chances of acclimatising these cottons under South Sind conditions were greater than in the Punjab.

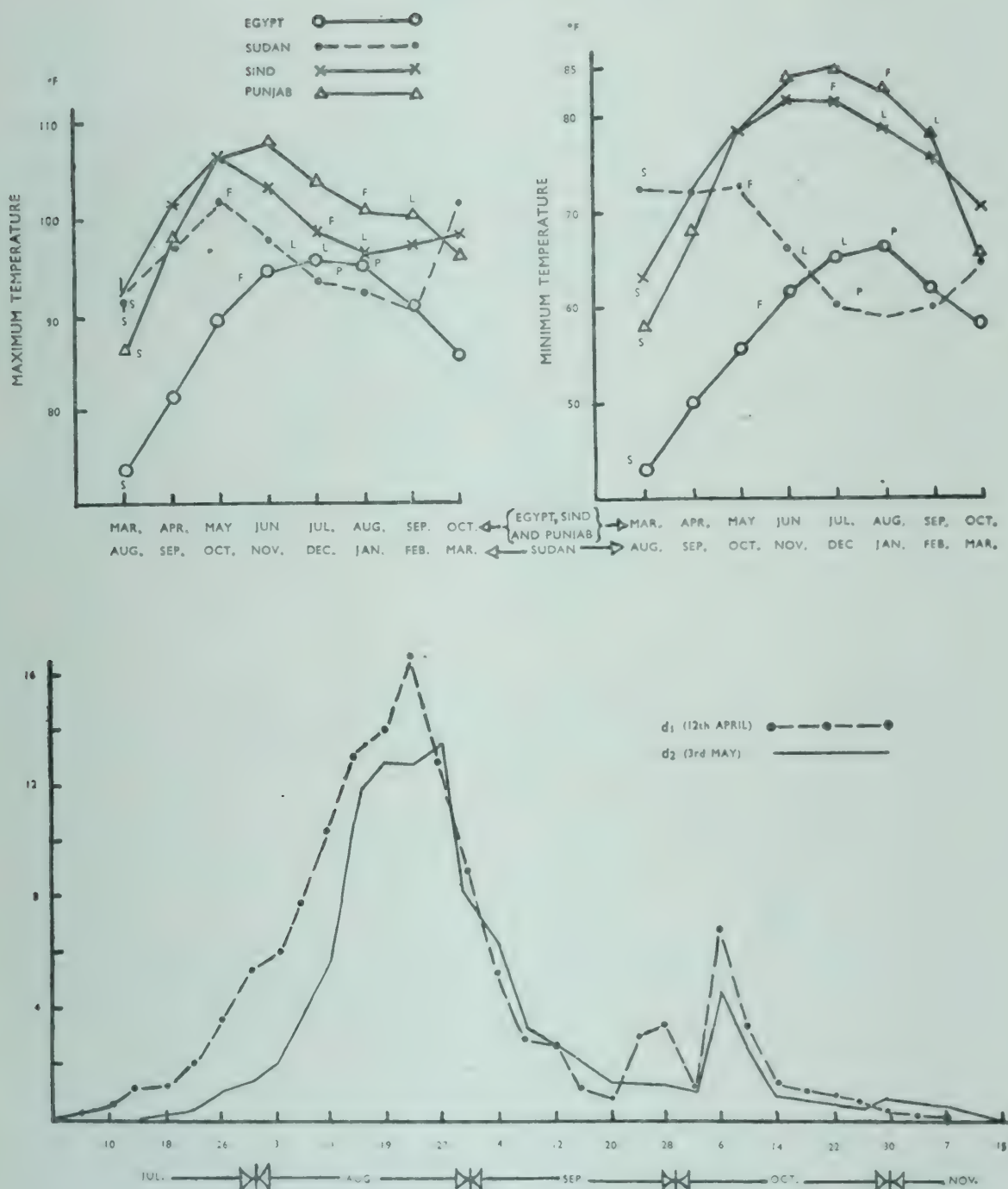


Fig. 19. Above: Maximum and Minimum Temperatures during the Growing Season in the Punjab and Sind and Egypt and the Sudan (Crowther's data); S = sowing time; F = flowering; L = maximum leaf weight; P = first picking

Below: Flowering Curve for the Sind Sea Island Cotton in Sind in 1947

On account of high temperatures and long summer days the crop in Sind also produced a more luxuriant vegetative growth than in Egypt or in the Sudan (Table 34).

TABLE 34. GROWTH CHARACTERS OF COTTON IN SIND EGYPT AND THE SUDAN,

Sowing date	Sind		Egypt*	Sudan
	12th April	3rd May	March	August
Height in cm.	169	144	72	103
Number of nodes per plant	64.6	50.4	23.1	29.5
Dry weight in gm. per plant	221.4	226.2	74	192
			(per hole)	(per hole)
First fruiting node	14.1	16.4	7	13
Bud initiation period in days	50.4	60.2	68	45
Square period in days	19.0	18.6	Not given	
Boll period in days	46.8	45.7	52	65-68
Number of bolls per sq. yd.	24	24	64	45
Boll weight in gm.	1.57	1.79	2.81	2.72

* Crowther (1934, 1936)

The dry weight per plant was nearly thrice the dry weight per hole in Egypt. It was also higher than in the Sudan. This difference in the dry weight in the three regions may be due to the differences in temperature, higher temperature producing greater amount of dry matter in Sind.

Though the first fruiting branch appeared at a higher node in Sind than in Egypt the number of days that elapsed after sowing for the appearance of the first flower bud was less in the former than in the latter region.

There was no information in the data collected by Crowther (1944) with regard to the square period under Egypt conditions. The square period in Sind was 19 days. This was slightly longer than the square period determined for American cottons in Sind.

The maturation period of bolls was shorter in Sind than either in Egypt or in the Sudan. Thus the climatic conditions in Sind favoured rapid maturation of bolls. Even though the maturation of the crop occurred at a quicker rate in Sind than in Egypt, the crop finished off earlier in Egypt. This was due to the fact that the early formed buds and flowers in Sind did not mature into bolls. Only the flowers that were produced from the month of August were found to develop into bolls. The crop in Sind was consequently ready for the first picking towards the end of September or beginning of October, i.e., about 6½ months after sowing while the crop in Egypt gave the first picking

in 5½ months after sowing.

Though the vegetative growth of *barbadense* cottons in Sind was vigorous the total number of bolls produced per unit area was much less in Sind than in Egypt or in the Sudan (Dastur, 1949). The bolls per square yard in Egypt were nearly three times the bolls produced for the same area in Sind (Table 34). The bolls were also smaller in size. The weight of *kapas* per boll was 1.5 gm. to 1.7 gm. in Sind while it was nearly 2.7 gm. to 2.8 gm. per boll in Egypt or in the Sudan.

Thus fewer number of bolls and their smaller size in Sind reduced the yields of these cottons under Sind conditions. The bolls produced in the Punjab by the same cotton were still fewer in number and smaller in size and the yields were still lower in the Punjab than in Sind.

It was an erroneous belief held in the past that the climatic conditions in Sind were similar to those that prevailed in Egypt. The cotton plant in Egypt was exposed to a milder climate than in Sind. The temperature in Sind was higher than in Egypt during the first three and a half months of the growth of the cotton plant. The temperature was still higher for a longer period in the Punjab. It is possible that this higher temperature may be promoting the vegetative growth of *barbadense* types but caused suppression of the fruiting branches.

The *hirsutum* cottons grown in Sind and the Punjab on the other hand came into flowering when the assimilatory activities of the crop were high and the temperature was low. They were also found to produce normal fruiting at a lower concentration of nitrogen in the leaves as there was not much difference between the nitrogen contents of the leaves between *hirsutum* and *barbadense* cottons during the fruiting period. Consequently the yields of *hirsutum* were much higher than the yields of *barbadense* types.

MYSORE •

Egyptian cottons were also grown at two places, viz., Mandya and Babbur Farms in Mysore State where water from the V. C. Farm canal became available from the Krishnaraja Sagar Reservoir. The climatic conditions are very mild in this region as compared to Egypt. The maximum temperature fluctuated during the year between 83° to 98°F. and the minimum temperatures from 58° to 75°F. The rainy months are April-May and September-October though small amount of rain is also received during the remaining months of the year.

The sowing date experiments were first conducted for four years, by Doraswami and Iyengar (1951), from 1942 onwards with five varieties of Egyptian cottons and they concluded from the results of their experiments that the best sowing time for the cottons was from mid-October to mid-December and Giza 12 and Giza 7 gave an yield of seed cotton varying from 500

to 600 lb. per acre. They also conducted manurial trials and found that higher yields were obtained with an application of 100 lb. nitrogen. In this particular experiment the yield of unmanured plots was only 139.7 lb. per acre while with 100 lb. nitrogen it was found to be 426 lb. per acre. Both these findings of Doraswami and Iyengar (1951) could not be confirmed as such high yields of 500 to 600 lb. were not being obtained and there was no response to nitrogen in numerous experiments conducted in a scheme financed by the Indian Central Cotton Committee to study the physiology of these cottons in Mysore. It started work in 1952 and many important features have since then come to light and they will be briefly summarised here (Unpublished).

A number of manurial trials were conducted at the two farms using varying doses of nitrogen from 33 lb. to 100 lb. in the form of ammonium sulphate. But in all these trials application of nitrogen was not found to produce any increase in yield, in all the experiments. The yield of unmanured plots also stood in the neighbourhood of 200 lb. per acre. Thus contrary to the results reported by Doraswami and Iyengar (1951), the yields of seed cotton were very low and manuring with nitrogen did not increase the yields.

In order to elucidate the causes for the lack of response to nitrogen the leaves, stems and fruiting parts of the plants from a manurial experiment consisting of three levels of nitrogen were analysed every fortnight from the sowing time up till picking and study of the results obtained indicated that the concentration of nitrogen in the leaves was high throughout the season, varying from 4.5 to 3 per cent. This indicated that nitrogen did not travel to the bolls as was usually the case. Thus added nitrogen remained unutilised for boll formation. The concentration of potash in the leaves on the other hand appeared to be below normal in comparison to nitrogen. Thus N_2/K_2O ratio was very high. It is normally less than one at maturity while it was nearly 1.5 in this case. It was, therefore, concluded that the potash requirements of these cottons were not met with from the soil. Later on it was found that the phosphate requirements of the crops were also not met with from a study of N_2/P_2O_5 ratios in the leaves. The normal ratios of three elements N P K in the leaves when crop matures has been found to be in other places 3:1:3 while it was about 6.1:1:3.2 at the time of first picking at Mysore (Dastur, 1956).

In view of these findings, an experiment comprising of all combinations of nitrogen, potash and phosphoric acid was laid out in the cotton season of 1954-55 at V.C. Farm and in 1955-56 at Babbur Farm. In the former tract the crop was planted in November and in the latter in June. Various observations were recorded on the crop such as the dry weight per hole, rate of flowering, setting percentage, boll number per square yard, boll weight, number of seeds per boll, seed index, lint index and technological properties of lint. The effect of different treatments can be seen from Table 35.

TABLE 35. EFFECT OF DIFFERENT TREATMENTS ON PHYSIOLOGICAL CHARACTERS

Treatment	Number of flowers (per sq. yd.)	Setting percent- age	Number of bolls (per sq. yd.)	Boll weight (gm.)	Number of seeds (per boll)	Weight of 100 seeds (gm.)	Lint index
Control	112.3	37.1	41.6	1.89	14.4	8.52	4.01
N	105.3	38.8	40.8	2.08	16.1	8.55	4.42
P	143.6	45.6	65.6	2.31	15.4	10.50	5.13
K	116.6	48.6	56.7	2.06	16.4	9.40	4.61
PK	99.9	47.6	47.6	2.04	15.4	8.92	4.34
NP	118.8	45.3	53.8	2.17	16.0	9.30	4.59
NK	152.8	38.8	59.4	2.13	15.9	8.40	4.19
NPK	173.8	50.9	88.0	2.45	17.5	9.42	4.78

Best growth and yield were obtained from plots receiving all the three fertilizers. The maximum dry weight per plant under this treatment was 139 gm. as compared to 119 gm. in the control plots. There was no effect of nitrogen alone on any growth character but a marked effect of potash and phosphoric acid singly and in combination with nitrogen was visible on the flower production, boll number and boll weight. The seed index and lint index were highest in the case of phosphate treatment. The number of seeds per boll remained, however, unaffected in any combination of the three fertilizers. This defect in the development of the boll, therefore, remained to be remedied.

The results of the total yields per acre under different treatments are given in Table 36.

TABLE 36. YIELD IN LB. PER ACRE

	Control	N	P	K	PK	NP	NK	NPK	
Yield	217.2	195.7	337.7	260.2	258.1	260.2	311.9	483.9	C. D. 5% =70.3 lb.
Fruiting index	0.21	0.19	0.24	0.29	0.28	0.29	0.30	0.37	S. E. as % of Mean 8.3
Strength index	6.96	7.31	7.26	6.89	6.87	6.99	7.24	6.96	

Nitrogen alone had again not given any increase in the yield while increases due to potash were found to be significant and the interaction NK also came out to be significant indicating the need for potash application when nitrogen is added. The increase in the yield by application of phosphate also was significant though the interaction NP fell short of significance. The necessity of phosphate application when nitrogen was used was, however, quite evident.

The efficiency of seed cotton production (quantity of seed cotton produced per unit dry weight) was found to be the highest in NPK treatment while it was the lowest in nitrogen treatment. The application of potash and phosphate also increased the efficiency of the plants for seed cotton production. With the application of nitrogen the vegetative growth alone was increased.

Though the various growth characters and yield were improved by the use of potash and phosphoric acid, the fibre qualities remained unaffected. They neither decreased the immaturity of fibres nor improved the pressley strength index. More than 50 per cent. of the fibres remained fully or partly immature, while the pressley strength index remained at about seven.

It is now attempted to adjust the doses of the three fertilizers to produce the maximum effect on the growth and yield and to see if any improvement in the number of seeds and fibre qualities can be produced. These investigations are in progress.

Similar experiment was laid out at Babbur Farm situated at a distance of about 100 miles north of Bangalore in June, 1955. The climatic conditions at Babbur Farm differed slightly from the climatic conditions at V. C. Farm. The main difference was in the maximum and minimum temperatures as at Babbur, the crop was sown in the month of June while at Mandya it was planted in November. During the early stages of growth the maximum temperatures at Babbur were higher than at the corresponding stages of growth at V. C. Farm. Similarly, the night temperatures were higher at Babbur than at Mandya. The effect of higher temperatures was reflected on the production of dry matter per plant. The dry weight per hole (two plants) was found to vary from 260 gm. to 340 gm. as compared to 100 gm. to 130 gm. at Mandya.

Another important difference was the absence of response to potash on yield while significant response on yield was obtained by the application of 100 lb. of P_2O_5 (Table 37).

TABLE 37. YIELD IN LB. PER ACRE

Control	N	P	K	PK	NP	NK	NPK
416.9	393.6	502.8	345.3	394.6	411.9	354.6	620.0
C.D. 5% 97.75							

The analysis of the leaves indicated that N_2/K_2O ratio reached unity at this farm.

The level of yield was also higher at this farm than at V. C. Farm, Mandya.

Thus, though the yields have been increased by the use of three fertilisers, the other defects still remain to be remedied. They are: (i) fewer number of seeds per boll; (ii) week immature fibres; and (iii) accumulation of nitrogen in the leaves. It is, therefore, first necessary to determine in what form

nitrogen remains locked up in the leaves. Once this is known it may pave the way for further investigations.

Another difficulty in the successful cultivation of cottons in Mysore State is the untimely rainfall at the fruiting stage. When these cottons are planted in November, the bolling period coincides with heavy rains in April-May. If these are planted in the month of June, the fruiting period coincides with heavy rains in September-October. The bolls under these conditions are not found to mature and open normally. They are also attacked by various fungi. It is, therefore, necessary to select an early maturing strain of Giza 12 to escape the rainy weather at the fruiting period, as far as possible.

Cotton is cultivated under rainfed conditions in Dharwar district on an area of about six lakh acres. Two varieties are in vogue, viz., Jayadhar (*G. herbaceum*) and Laxmi (*G. hirsutum*). In 1953-54 the area under Jayadhar was about two lakh acres and that under Laxmi nearly four lakhs. The yields of these varieties over the whole district average less than 200 lb. of seed cotton per acre and the problem of devising ways and means for increasing the yields to a more satisfactory level was very urgent.

The district can be divided into two regions as regards climate on the basis of the distribution of rainfall: (i) the transition tract represented by Dharwar, Hubli, Haveri and Rannebennur; and (ii) the dry eastern part represented by Gadag, Ron, Navalgund and Nargund talukas. The transition tract has an average rainfall of about 28 inches distributed between the months of April and October. The rainiest month is July, followed by October. The dry eastern part has an average rainfall of about 24 inches between April and October. September and October are the rainiest months.

The maximum summer temperature rises above 100°F. during March, April and May at Gadag whereas it rarely touches 100°F. at Dharwar.

Cotton is mostly grown on deep black and medium black soils in Dharwar district. The former type predominates in the transition tract and the latter in the dry eastern tract. In the transition tract, e.g., at Dharwar, the practice is to start sowing pulses like mung, (*Phaseolus radiatus*, L.), udid (*Phaseolus mungo*, L.) and alsandi (*Vigna catjang*, walp.) as soon as the monsoon commences, i.e., in the first or second week of June. Thereafter, groundnut (*Arachis hypogea*, L.) is sown by the end of June. The sowing of jowar (*Sorghum vulgare*, Pers.) is taken up by about the middle of July. Cotton sowings begin in the third or fourth week of August.

In the dry eastern tract, e.g., at Gadag, the practice is to sow groundnut, if possible, in the first week of July, jowar in the second or third week of July and cotton in the third week of September after the north-east monsoon commences.

A scheme for determining the physiological causes of the low yields of Laxmi and Jayadhar cottons was prepared by the senior author in 1948 as, during his visit in 1948-49, it appeared to him from the study of the various

features of the growth of the crop that the vegetative structure produced by these cottons was too small to mature larger number of bolls. The study of the rainfall records and the temperatures indicated that those cottons can be planted much earlier than according to practice in Dharwar and Gadag areas. The reasons for commencing cotton sowings as late as the third or fourth week of August in Dharwar area and from fourth week in September in Gadag area cannot be determined now as there was nothing on records. The reasons that were put forward were the heavy showers in September in Gadag area that were supposed to affect the growth of Dharwar-American cotton and increase the incidence of the red leaf blight. No reason was given for late planting of *herbaceum* cottons in Dharwar area.

The rainfall conditions were favourable for planting the crop in the last week of July instead of August in Dharwar area as sufficient rains were received by that time while it was put forward that sufficient rains were not received in August in Gadag area to start cotton sowings earlier. The rainfall data, week by week, was, therefore, studied for the last 22 years, i.e., from 1934 to 1956 for Gadag and it was found that only in one year 1937, the rainfall was inadequate to start sowings of cotton until the end of September. In all the rainfall tracts, the late arrival of rains was not of uncommon occurrence but in this particular case enough rains were received in both the tracts to plant the crop earlier than the normal practice. Cottons were not sown early enough to give adequate time for vegetative growth before the reproductive phase set in.

Though the scheme for determining the physiological causes of low yields of seed cotton was prepared by the senior author in 1949-50 and though it came into operation in 1952, preliminary experiments to study the effect of earlier planting of the crop were already conducted in 1949-1950 and 1950-51, by the senior author in collaboration with the Cotton Breeder, Dharwar.

In 1949, an experiment was undertaken at Gadag to study the effect of early sowings in combination with different spacings. The experiment was repeated in 1950. Here also, the first date of sowing was earlier by a fortnight than that adopted on the plant breeding centre, the second date of sowing corresponds to the commencement of sowing by cultivators and the third date of sowing approximately corresponds to the last sowing done by cultivators in that area. The spacings used were $2' \times \frac{1}{2}'$ and $2' \times 1'$. The average yields obtained have been calculated on an acre basis (Tables 38 and 39).

The data given in tables shows that early sowing of cotton in Gadag area resulted in significantly higher yields. In 1949-50 the crop sown on the 2nd September gave an yield of 929 lb. per acre as compared with the yield of 178 lb. per acre in the case of crop planted on the 2nd October. Similar results were again obtained in 1950-51 cotton season where the early sown crop again gave 200 lb. more seed cotton than the yield in the crop planted

on the 24th September. The late sown crop was also not benefited by close spacing.

TABLE 38. YIELD OF LAXMI AT GADAG IN 1949-50 (lb. per acre)

Sowing date	Spacing			Mean for sowing dates	S.E.	C.D.
	2' x ½'	2' x ¼'	2' x 1'			
2-9-1949	929	865	826	873	68.67	139.4
17-9-1949	640	427	504	524	—	—
2-10-1949	173	327	204	235	—	—
Mean for spacings	581	540	511	544	—	—

The differences between the spacing are insignificant and the interaction between spacings and sowing dates is also not significant.

TABLE 39. YIELD OF LAXMI AT GADAG IN 1950-51 (lb. per acre)

Sowing date	Spacing			Mean for sowing dates	S. E.	C.D.
	2' x ½'	2' x ¼'	2' x 1'			
25-8-1950	446	420	386	417	—	—
9-9-1950	325	379	358	354	41.14	33.51
24-9-1950	248	245	243	244	—	—
Mean for spacings	338	348	329	338	—	—

The differences between the spacings are insignificant and the interaction between spacings and dates is also not significant.

These sowing date experiments were, therefore, continued in the newly started physiological scheme for another four years both at Dharwar and Gadag using both the varieties of cotton.

In Table 40, the effect of the three sowing periods on the yields of Jayadhar and Laxmi for four years at both the centres are given. The means of four seasons for each sowing date and for each variety are also given. The seasonal variation in the yield of each variety can also be seen from the table. At Gadag only two sowing dates were kept in 1953-54 as early sowing could not be carried out due to lack of soil moisture when the first sowing was intended to be done.

The mean yield of Jayadhar at Dharwar centre has remained fairly constant at about 500 lb. per acre for the three years 1952-55, while 1955-56 has proved to be a bad season for this variety. The mean yield of Laxmi at the same centre has fluctuated from year to year from 332 lb. to 466 lb. per acre. Jayadhar has yielded more than Laxmi at Dharwar.

At Gadag the yield of Jayadhar has shown greater variation from year to year than at Dharwar. The same is true of Laxmi. Laxmi crop suffered heavily from immaturity of seeds and lint in 1954-55 and the yield was reduced to 143 lb. per acre. Jayadhar has again out-yielded Laxmi at Gadag.

TABLE 40. MEAN EFFECT OF SOWING TIME ON YIELD 1952-55 (yield in lb. per acre)

Sowing time	1952-53	1953-54	1954-55	1955-56	Mean	1952-53	1953-54	1954-55	1955-56	Mean
	Jayadhar					Laxmi				
	DHARWAR CENTRE									
Very early	627	570	527	297	503	612	382	671	489	538
Mid early	571	522	573	253	480	441	308	521	427	424
Normal	424	453	513	176	392	232	307	435	165	285
Mean	541	515	538	242		431	332	542	360	
S.E.	29.9	13.9	N. S.	N. S.		29.9	7.1	29.3	8.1	
S.E. % of mean	5.8	2.7				6.9	2.1	5.4	2.3	
	GADAG CENTRE									
Very early	509	—	564		536	406	—	202	589	399
Mid early	461	715	577	Trial	584	358	350	168	429	326
Normal	359	572	384		438	305	224	59	237	206
Mean	443	644	508	not		350	287	143	314	
S.E.	16.4	14.7	24.2			16.4	14.7	19.2	47.0	
S.E. % of mean	3.7	2.3	4.8	conducted		4.6	5.1	13.4	11.1	

At Dharwar very early sowing means crop sown in the third or fourth week of July, mid-early means crop sown in the first or second week of August and normal sowing means crop sown in the third or fourth week of August.

At Gadag very early sowing means crop sown in the last week of August, mid-early means crop sown in the middle of September and normal sowing means crop sown between late September and early October.

Normal sowing time of cultivators at Dharwar for Jayadhar appears to be too late to produce enough vegetative growth so as to mature a larger number of bolls. The crop has, therefore, to be sown early. In three years out of four, very early sowing done in the third or fourth week of July and mid-early sowings done in the first and second week of August, have given higher yields than normal sowing, while in 1954-55 all sowings have given nearly equal yields.

The mean difference between very early sowings and normal sowings for the four years for Jayadhar is 111 lb. per acre while the mean difference between mid early sowing and normal sowing for Jayadhar for four years is 88 lb. per acre. Thus the cultivator is expected to gain to the extent of 22 to 28 per cent. over his normal yield by practising early sowing of Jayadhar.

The same conclusions hold good for Laxmi cotton sown at Dharwar, where it was not, until late, normally grown. Very early sowings in all the four years have yielded better than normal sowing, the magnitude of increase depending on the seasonal conditions. In 1952-53, 1954-55 and 1955-56 the increase in yield due to very early sowings was nearly 200 to 400 lb. per acre while there was a difference of only 75 lb. in 1953-54. The mean increase by practising very early sowings for four years was about 253 lb. per acre while the difference between mid-early sowing and normal sowing was

139 lb. per acre. A cultivator is, therefore, expected to get an increase in yield varying from 49 to 90 per cent. by practising early sowing of Laxmi at Dharwar.

The results of the trials undertaken for three years on Jayadhar and for four years on Laxmi at Gadag are given in Table 40. All results indicate the benefit derived by early sowing of both Jayadhar and Laxmi. The seasonal conditions were bad in 1954-55 and on account of the immaturity of seeds and lint the level of the yield was low. The increase in the yield obtained for Jayadhar by practising very early sowing was about 98 lb. per acre and by practising early sowing it was 146 lb. per acre on an average for three years. The cultivators of Gadag are expected to get 22 to 33 per cent. more yield by taking up early sowings of Jayadhar. Average increase obtained by very early sowing of Laxmi cotton was 193 lb. per acre and that obtained by sowing it early was 120 lb. per acre. The cultivators at Gadag are, therefore, expected to get 54 to 89 per cent. more yield by resorting to sowing Laxmi cotton sufficiently early.

Thus the optimum period for sowing cotton at Dharwar appears to be between third week of July and first week of August and at Gadag from last week of August to middle of September. Late September and early October sowings that are practised at Gadag must, therefore, be stopped.

EFFECT OF MANURING ON YIELD

Manurial trials were also conducted from 1952 to 1955 at both centres using both varieties of cotton. The doses of nitrogen used were 0, 20, 40 and 60 lb. in the form of sulphate of ammonia, applied before sowing.

It was concluded from these experiments that though the yield can be increased by manuring, the increase was found to be small and uneconomical for any nitrogen level. If we consider that the cost of 1 lb. of nitrogen in the form of sulphate of ammonia as Re. 1 and the value of 3 lb. of seed cotton at Re. 1 then there should be an increase of at least 60, 120 and 180 lb. of seed cotton on application of 20, 40, and 60 lb. of nitrogen, respectively, to make it economical. This was not found to be the case.

Some data given in this chapter were collected by the staff of the Schemes for Cotton Physiological Research at Dharwar and at Mysore and they will be published along with other results elsewhere.

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CHAPTER II

AGRONOMY

The cultivation of cotton in India is concentrated in the central and western parts of the Indo-Gangetic alluvium and the black cotton soil tracts of the Peninsula, though, to a limited extent, the crop is also grown on the hill slopes of Assam in the east and on the lateritic, coarse, sandy or gravelly red soils in the central and southern parts of the country. Broadly speaking, the indigenous or Asiatic varieties are grown almost entirely under conditions of natural rainfall, and the American varieties raised on irrigated lands. The irrigated crop is mostly confined to the Indo-Gangetic plain and a few lighter soil tracts in Mysore and Madras States.

The crop yields in India are usually low, perhaps the lowest in the world. The average yield of lint for irrigated and rainfed cottons is only about 200 pounds and 80 pounds per acre, respectively. This compares very unfavourably with the yields of 450 pounds in Egypt and 350 pounds in the Sudan, where the crop is grown under irrigated conditions. Even in the United States of America, where cultivation is done mostly without irrigation, the average yield of lint is about 300 pounds per acre. The low yields in India are partly due to the prevailing practice of mixed cropping, under which cotton does not occupy the whole land but is grown mixed with other crops. However, the principal causes of poor yield are: low quality of seed, lack of proper manuring, precarious rainfall, virtual absence of water and soil conservation measures and inefficient control of pests and diseases. Moreover, removal of large quantities of cotton stalks and other crop residues every year for use as fuel also impoverishes the soil continually. This is a serious loss, particularly when no steps are taken ordinarily to make it good before sowing the next crop.

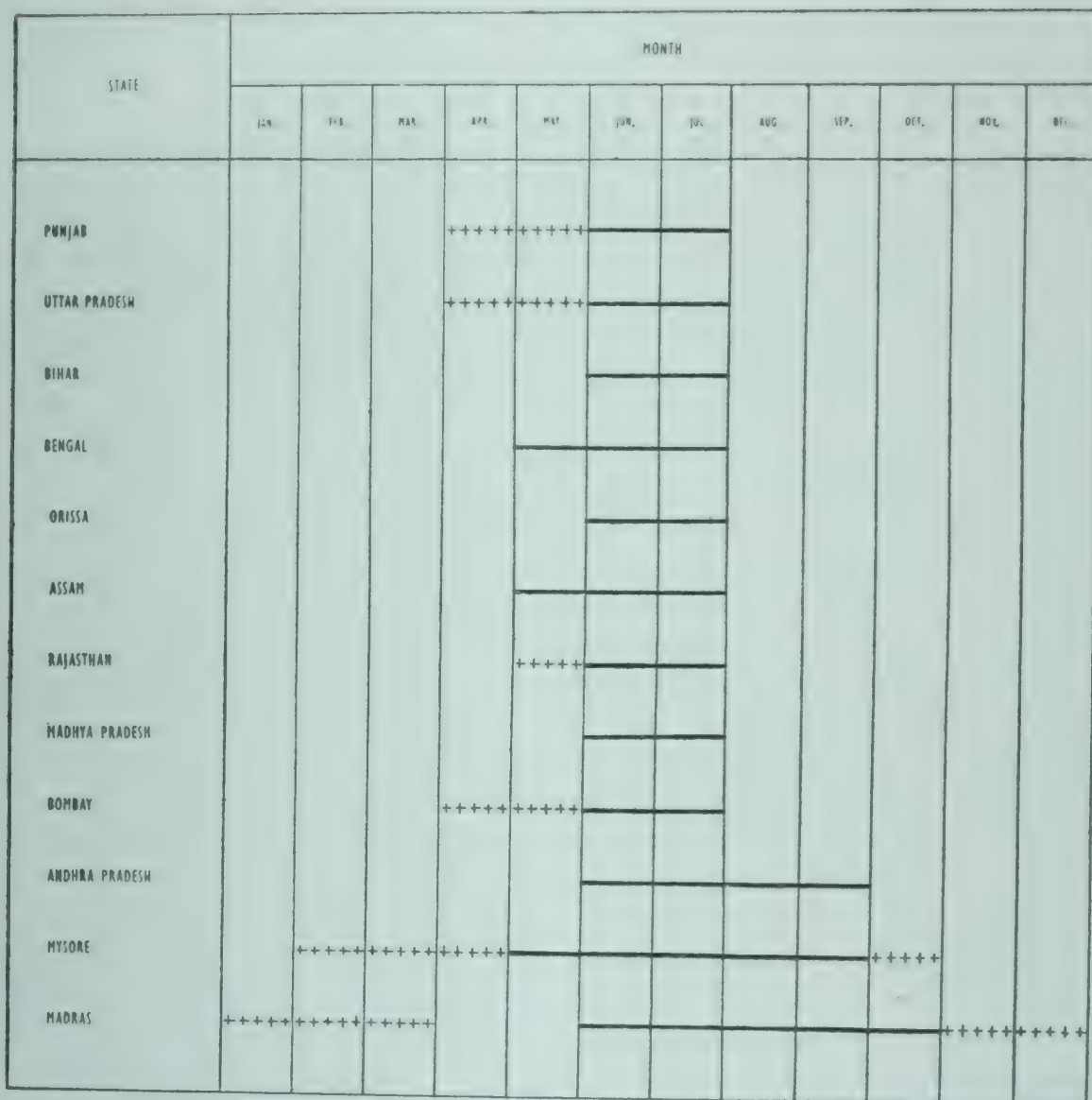
SEASON OF SOWING

The sowing season varies considerably from one part of the country to another, owing to differences in climate, soil, varieties grown, and character of cultivation, i.e., whether the crop is raised as rainfed or under artificial irrigation. In fact, there is practically no month in the year when sowings do not take place in some part of the country. The months in which the crop is sown in different States are shown in Figure 20. Since the weather conditions vary a great deal from year to year, the optimum time for sowing is not constant in any district. Generally speaking, a minimum soil temperature of 60°F. is necessary for the germination of seed. Excessive soil moisture affects both germination and subsequent growth very adversely.

In the Punjab, Uttar Pradesh, Bihar, Orissa, Bengal, Rajasthan, Madhya Pradesh, Khandesh Division of Bombay State and northern districts of Andhra Pradesh, cotton is grown as a *kharif* or autumn-harvested crop. The sowing of the rainfed crop in these tracts is done with the commencement of the monsoon in June or July, whereas the irrigated crop is sown one or two months earlier, i.e., in May or April, depending on the variety grown (*desi* or American). In Uttar Pradesh, the irrigated crop is sometimes sown as late as the first half of June. In Gujerat, the bulk of the unirrigated crop is sown in June or July, but in some parts of Baroda, Broach and Surat districts the farmers sow the seed in dry soil in May, in anticipation of the monsoon rains.

In North Mysore and southern districts of Andhra Pradesh, which benefit chiefly from the receding south-west monsoon and a few showers of the north-east monsoon from October to December, the crop of *desi* cotton grown on the deep black soils is sown in the latter half of August or early in September. Late sowing ensures that the produce will mature at a time when the danger from the late rains is practically over. The sowing of mixed crops of cotton and *setaria* is done in July-August. On lighter types of soils, a quick-maturing *arboreum* variety, grown pure or mixed with *setaria* or groundnut, is sown in June or July. In Chinnapathi area of Visakhapatnam and Srikakulam districts, the crop is sown either in May-June or in December-January. In the latter case, it is sown in wet land after harvesting a crop of paddy. In the *kar ragi* tracts of Mysore, which receive early rainfall, American cotton sowings begin from the middle of May. In other tracts of this State, where south-west monsoon starts at the normal time, the sowings are done in June or July. Irrigated American Upland cotton in the canal tracts of Mysore is sown in the second half of February or the first fortnight of March. On the other hand, in Madras, which receives rain partly from the south-west and partly from the north-east monsoon, the major portion of the rainfed crop is planted in September-October, the remainder being sown a little earlier. The irrigated crop of Uganda-American cotton in Madurai, Ramnathapuram and Tirunelveli districts of Madras is grown during the hot weather, sowing being done usually in February or March. The crop matures in June or July and the produce is often spoiled by the south-west monsoon rains. The same variety grown in South Arcot, Chingleput, Chittoor and Nellore districts is planted in December or January. The major portion of the produce of this crop matures before the arrival of the south-west monsoon in July and thus escapes damage from rain. In some parts of Salem district, irrigated Cambodia cotton is sown in September or October after a crop of summer *jowar* (*cholam*), which is harvested in July. The cotton crop is harvested in the dry season from mid-February to mid-March, and a crop of white *jowar* (*chitrai cholam*) is planted immediately afterwards, in the third week of March.

In Tanjore delta area, growing a single crop (early-maturing *sambha* paddy), and the cultivation of Punjab-American 216F cotton under irrigation



+++++++ IRRIGATED CROP

----- RAINFED CROP

Fig. 20. Showing Seasons in Different States

as a second crop has been successfully introduced in recent years. This second crop is sown in December or January in the stubble after paddy has been harvested.

Numerous experiments have been conducted in different States for determining the optimum date for sowing cotton in each area. Due to wide variations in the date of commencement of monsoon rains from year to year in the same locality, the soil moisture conditions needed for good germination do not occur on any constant date annually. Therefore, no fixed date can be laid down as optimum sowing date for any place. However, it has been found that early sowing of the crop usually increases the yield and sowing later than the normal season reduces it. The risk of bad weather following an early sowing is certainly there, but the advantages outweigh the disadvantages. Moreover, in many places, the occurrence of a long break after the first one-inch shower in June is not frequent. A study of rainfall records for the two districts of Marathwada over a period of 40 years indicates that in 9 out of 10 years the course of monsoons after the first one-inch shower of rain is such as would ensure good germination. Early sowing has often been found to improve the quality of the produce also. It has been observed further that in the Peninsular India as well as in the black soil tracts of Rajasthan, Madhya Pradesh, Khandesh and Gujerat the sowing of American varieties with irrigation, four to six weeks before the monsoon, and then treating the crop as largely rainfed, increases the yield two-and-a-half to three times. This, however, requires the irrigation of the crop in mid-summer, which may not be possible at present in many localities. The completion of large irrigation projects now under construction in some of these States will change the situation materially, and it will then be possible to grow long staple American cotton under irrigation on a fairly large area in these tracts.

On the basis of the length of the crop season, the cotton varieties grown in India may be broadly classified into two groups: (i) those that require eight or nine months to grow; and (ii) those which take only five or six months to produce a crop. The varieties of the first group are generally grown in irrigated tracts or in the regions in which the growing season is long and the soils are water-retentive. The varieties of the second group, on the other hand, are cultivated in areas in which frosts occur during the winter, or the soils are comparatively light, or the cultivation of the crop depends wholly on rains received in a short-duration monsoon. Many of the cotton varieties in cultivation are time-bound. For instance, *herbaceum* types are usually sown in August or September and harvested from January to April. Even if they are sown earlier, say in June or July, they will still mature in the normal period from January to April. Some types of *arboreum* cotton are also time-bound. On the other hand, a few *hirsutum* varieties possess a wide adaptability. They are sown in March-May in North India and in October-December in South India. In Madras State and in the adjoining parts of Andhra Pradesh and

Mysore, cotton can be sown practically at any time, provided, adequate soil moisture is available and soil temperature is above 60°F. to ensure good germination of seed and satisfactory plant growth. The soil and air temperatures in this region are usually sufficiently high throughout the year for the germination of the seed and growth of the crop.

CROP ROTATION

Like most crops, cotton gives better yields when grown in rotation with other crops. Indian farmers are generally well aware of the benefits of crop rotation and it is, therefore, seldom that cotton is raised in the same field for two or more successive seasons. The crops included in the rotation and their sequence vary a great deal in different parts of the country depending as they do on the nature of soil, climatic conditions, soil erosion, prevailing prices, farmers' own requirements, existence or absence of irrigation facilities, occurrence of plant diseases and pests, time of sowing and harvest of different crops, etc.

The most commonly practised rotations for irrigated as well as unirrigated cottons in the Punjab, eastern part of Bikaner (Rajasthan), Uttar Pradesh and Bihar are cotton-wheat, cotton-jowar (sorghum) and cotton-wheat-toria (*Brassica sp.*). In some parts of the Punjab, leguminous fodder crops, such as *senji* (*Melilotus parviflora*), *shaftal* (*Trifolium resupinatum*) and *berseem* (*Trifolium alexandrinum*) are sown in the standing crop of irrigated cotton at the end of October or in November as a second crop. Similarly, in certain areas of Uttar Pradesh, farmers sow field peas, *berseem* and *methi* (*Trigonella foenum-graecum*) in the standing crop of cotton in November before taking a crop of wheat in the following year. The growing of the legume crop in the interval between cotton and the following wheat is a commendable practice. Field peas, *senji*, *barseem*, *shaftal* and *methi* not only provide additional income, but also help in building up soil-fertility. In recent years, the growing of an early maturing variety of *mung* (green gram) in the fallow period following cotton harvest and preceding wheat sowing has been successfully introduced in large areas of Uttar Pradesh.

From experiments conducted in the Punjab, it has been found that a good crop of irrigated wheat can be grown as a second crop after the early-maturing Punjab-Americans 216F and 320F cottons. To ensure a really good yield of wheat, in such cases, the soil is adequately manured with farm yard manure and/or ammonium sulphate immediately after finishing the cotton harvest. This exhaustive rotation is, however, not recommended for initially poor soils. In the Punjab, the growing of *barseem* (Egyptian clover) before cotton has been found to have a very beneficial effect on the cotton yield. Wheat-gram-cotton is another useful rotation, which is practised fairly commonly in these areas.

In the black soil tracts of Rajasthan, Bundelkhand (Uttar Pradesh), Madhya Pradesh, Bombay, Andhra Pradesh and Madras, the usual rotation for rainfed cotton is cotton-*kharif jowar* (*Andropogon sorghum*). In certain areas, groundnut, tobacco, chillies, *ragi* (*Eleusine coracana*), gingelly, wheat, linseed and pulses like black gram, green gram, Bengal gram, etc., are grown in rotation, depending on the character of the soil and season. *Kharif* crops are preferred on the medium black soils, and *rabi* (spring-harvested) crops on water-retentive deep black soils. Accordingly, in some parts of Madhya Pradesh, Gujarat, Marathwada, Andhra Pradesh and Mysore, *rabi jowar*, wheat, linseed, lathyrus (*lang*) or gram are grown following cotton. *Rabi* cereal in Marathwada is usually preceded by a crop of early-maturing *mung*. In some localities in Gujarat, cotton is grown after cotton for two years. Similarly, in Karnatak, American cotton is sometimes grown year after year in the same land, but in such cases, the crop is generally manured with cattle-dung. In some other tracts, land is occasionally fallowed. It has been found that cotton grown after a year's fallow usually gives an exceptionally good yield. On light soils, *bajra* (Bullrush millet), and sometimes sesamum take the place of *kharif jowar* in the rotation. In Madras State, it has been observed that cotton crop grown after *cholan* (sorghum) gives a distinctly lower yield than the cotton crop grown after *cumbu* (Bullrush millet). The ill-effect of sorghum is ascribed to the presence of large quantities of sodium in the soil after sorghum than after Bullrush millet. It has also been found that the adverse effect of sorghum can be reduced materially or eliminated altogether if the millet crop is cut at the 'shot' blade stage and not allowed to produce grain. On red soils, cotton and *jowar*, cotton and *bajra*, cotton and groundnut, cotton and sesamum, cotton and castor, or cotton and *ragi* are commonly grown in alternate years. Irrigated cotton in these parts is grown in rotation with irrigated *ragi*, groundnut and garden crops, like chillies, tobacco, sugarcane, maize and vegetables.

In recent years, as a result of the efforts of the Agricultural Departments, the two-year cotton-*jowar* or cotton-wheat rotation in many parts of Bombay, Madhya Pradesh, Marathwada, Mysore, Andhra Pradesh and Madras has been increasingly converted into a three-year rotation by inserting a crop of groundnut between the cereals and the cotton crops. The rotation experiments conducted in Madhya Pradesh and Marathwada for several years have shown that cotton grown after groundnut gives 15 to 20 per cent. more yield than cotton grown after sorghum (*jowar*) or wheat. The two-year rotation of cotton and cereals is exhausting for most of the soils. The introduction of a short-season leguminous crop of *mung* or field peas as in Uttar Pradesh, or of a crop of groundnut as in the black and red soil tracts keeps down weed growth and also improves soil fertility. Broadly speaking, cotton should follow the leguminous crop in rotation and precede the grain or oilseed crop.

In many parts of the country, mixed cropping of cotton with other crops is also commonly practised. On the fertile black soils of Dhar district of Madhya Pradesh, Cambodia-American cotton is grown mixed with maize year after year. Sowing is done with the commencement of rains in the third or fourth week of June. The seed is mixed with maize in the proportion of 2 : 1 by weight and the mixture is sown at the rate of 24 pounds per acre. The maize crop is harvested in the middle of September and cotton continues to grow till the end of January. The dung manure applied for maize benefits the deeper rooted cotton also. In some other parts of Malwa tract of Madhya Pradesh, a mixture of American and *desi* varieties of cotton is grown. The seeds of the two varieties are deliberately mixed. It is claimed that the mixed crop gives a larger total yield than the pure crop of each does in the aggregate. In Nimar district of the State, cotton is sometimes grown mixed with *arhar* (*Cajanas indicus*) or groundnut.

In Madhya Pradesh and many parts of the Peninsular and southern India, rainfed cotton is grown mixed in varying proportions with *kharif jowar*, *ambadi* (Deccan hemp), horse gram, sesamum, coriander, melons, *bhindi* (lady's finger), and other vegetables and pulses. In Cocanada tract, mixed cropping of cotton, paddy, chillies, pigeon pea and groundnut is fairly common. On the hill slopes in Assam, cotton is sown mixed with paddy, *ambadi*, *bhindi*, marrows, and other vegetables and pulses. The plants of tapioca and pineapple are also sometimes found growing in the cotton crop in Garo Hills.

Intercropping of rainfed cotton is a common practice in the Peninsular India and some parts of Uttar Pradesh. One or two rows of *tur* (red gram) are planted after every eight or ten rows of cotton. In Mysore, three to five rows of *navane* (*Setaria*) are alternated with one row of indigenous cotton, more particularly when the cotton crop is sown rather late in the season. In places growing early cotton, *sajje* (*Pennisetum typhoideum*) or *jonna* (sorghum) takes the place of *Setaria*. The intercrop matures in about three months. Immediately thereafter, the interspace between the cotton rows is ploughed up or worked with a blade harrow. In parts of North Mysore, American Upland cotton is intercropped with groundnut, two rows of the latter alternating with one of the former. In Baroda, Broach and some parts of Surat district of Bombay State, one or two rows of early-maturing paddy are commonly planted between widely spaced cotton rows. Cotton seedlings growing in the deep black soils of these districts are often seriously damaged by heavy showers of rain falling in the early part of the season. Rice plants generally flourish in such rainfall. In years of light rainfall, cotton fares better than rice does. Rice is harvested in September or October. Thereafter the cotton plants grow vigorously and give a good yield if the soil is fairly fertile. In some parts of North Gujerat, where the rainfall is relatively less heavy, one row of castor is grown after every few rows of cotton. In South Andhra Pradesh and North Mysore, groundnut and inferior millets are planted as

intercrops. It has been found that the planting of one row of an improved *mungari* (early sown) variety of cotton after every eight or ten rows of the bunch variety of groundnut does not reduce the yield of the latter. Intercropping and mixed cropping not only serve as an insurance against total crop failure, but also reduce soil erosion, particularly if the plants of the subsidiary crop have a trailing habit. Furthermore, in an investigation on root rot (*Rhizoctonia* sp.) conducted in the Punjab, it was found that cotton intercropped with *moth* (*Phaseolus aconitifolius*) suffered much less from this disease than cotton grown as a pure crop.

In rare cases, the cotton crop is ratooned, or allowed to stand over for a second season. When cotton is ratooned, the plants are cut down to about nine inches above ground before the commencement of monsoon rains. The intervening space between the cotton rows is ploughed or hoed and occasionally manured. In some parts of Gujarat, cotton is grown after cotton for two years in succession. In Madras, Nadam cotton (*G. obtusifolium*) is allowed to stand for three years continuously. The plants of this cotton give either very little or no yield in the first year. In the second year, they produce a normal crop and in the third year, give a somewhat lower yield.

In practically all parts of the country, different varieties of perennial cotton are found growing in house compounds or backyards. Only a few individual plants are grown in such cases to meet domestic requirements. The plants are allowed to grow for several years in succession and watered, if necessary. Often times they grow into tall bushes and sometimes become fair sized trees, each producing three or four pounds of *kapas* (seed cotton) annually.

It would, thus, be observed that the cotton growers in India do not practice an inflexible system in respect of either the crops grown in rotation with cotton, or the sequence in which they are grown, or the areas allotted to them in successive seasons. Variations of rotation systems, crop sequence and areas allotted to different crops are introduced with long and short term changes in agricultural, economic or environmental conditions. Mixed planting of different crops simultaneously in the same field as an insurance against total crop failure in adverse seasons is an age-old practice and it is still of considerable importance in many parts of the country. Mixed cropping not only makes farming less risky but also ensures the optimum use of soil fertility. It also enables the farmer to grow simultaneously almost all the crops needed to meet his own requirements. This system appears particularly well suited to tracts in which the rainfall is highly precarious, soil fertility rather low, and the harvesting of crops is done by manual labour.

IMPLEMENTS

The tillage implements used for growing the cotton crop vary with the nature of the soil, the method of growing the crop and the different operations

of cultivation. The implements in common use are the *desi* plough, the *bakhar* or blade harrow, a beam leveller or clod crusher, single or multi-coultered wooden seed drills, *kolpa* or blade cultivator and a *khurpi* or hand hoe. In the Punjab and some of the other States in northern India, pegged or spike-toothed harrows and three tined hoes (*triphallies*) take the place of blade harrows (Figs. 21, 22 and 23).



Fig. 21. Meston Hindustan Plough

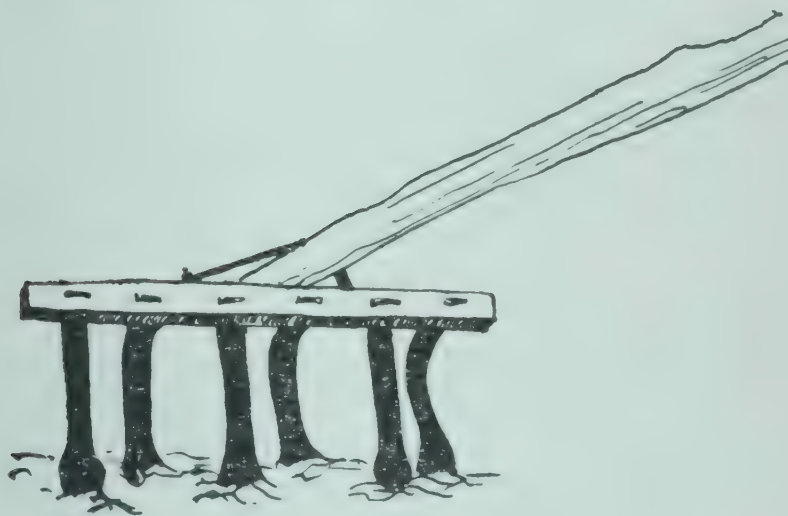


Fig. 22. Pegged Harrow

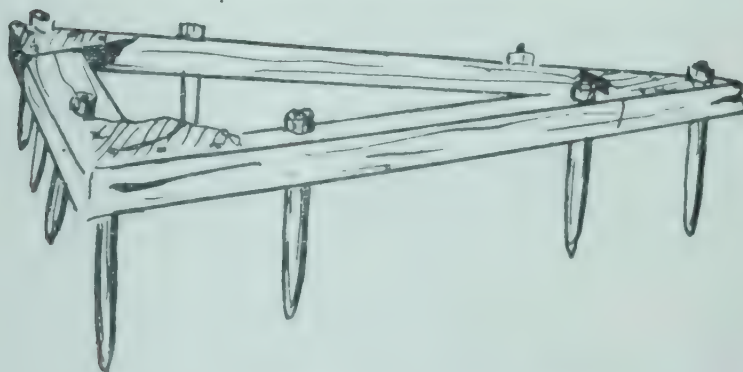


Fig. 23. Triangular Spike-Toothed Harrow

Initial ploughing on alluvial soils in the Indo-Gangetic plain and the red soils elsewhere is done with the *desi*, iron-shod wooden ploughs. These are light implements and are usually drawn by one pair of bullocks. They penetrate only three to five inches of soil, breaking it into small clods. The *desi* plough only stirs the soil and does not invert it. It is, thus, more of a 'cultivator' than a plough in the accepted western sense. Repeated ploughing is necessary to obtain a good tilth. Essentially similar in design in all parts of the country, the wooden plough varies in dimensions to suit the prevailing soil types, moisture conditions and the size of strength of the draft animals. Light mould-board ploughs, made wholly of iron, or partly of iron and partly of wood, are also commonly used in place of the *desi* ploughs. They are available in the market in variety to suit different soil conditions and purposes. These improved implements do the work more efficiently by inverting the soil and thus burying weeds and plant residues that may be remaining on the surface (Fig. 24).

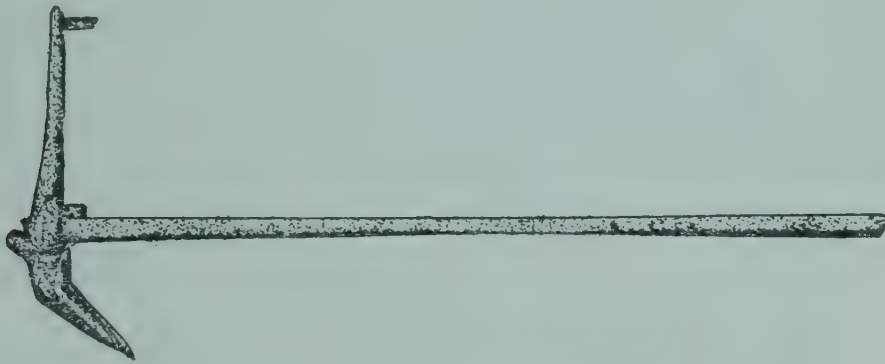


Fig. 24. *Munna* (*Desi* Plough)

In the black cotton soil tracts, the land receives the preparatory tillage by an implement called *bakhar* in Marathi, *kunte* in Kanerese, and *guntaka* in Tamil and Telugu (Fig. 25). The body of this implement is made up of a log of wood, rectangular or octagonal in shape, three to six feet in length,



Fig. 25. *Bakhar* (Blade Harrow)

twelve to fifteen inches in width and two to three inches in thickness. A handle is attached on the upper side of this log and a yoke pole for a pair of bullocks in front. The working part of the implement consists of a heavy blade or iron, two to four feet in length and two to three inches in width. The blade is attached to the log on its under side by means of two slanting wooden pegs, one near each end. In some parts of Madras, an improved *guntaka*, having a slightly curved blade fitted to an iron frame instead of a log of wood, is in use. When the *bakhar* is drawn forward in the field, the blade penetrates the soil to a depth of three to four inches, cutting the underground parts of weeds and leaving a good tilth if the soil is fairly moist. The *bakhar* is the most effective single implement for light and economic cultivation of the black soils. Its only drawback is that its repeated use forms a hard pan in the soil at a depth of four to six inches. However, an occasional deep ploughing remedies this evil. The blade harrow is also used for breaking clods, levelling land, or covering the sown seed by running it inverted after detaching the handle. If the clods are somewhat bigger, a clod crusher, consisting of a heavy beam of wood and six to seven feet in length, is used for breaking the clods. This beam of wood has two chains in front, which are fixed to a yoke, and it is drawn by a pair of bullocks. While working the implement, the operator stands on the log to weigh it down. This implement is also used for levelling and compacting the soil before sowing (Fig. 26).

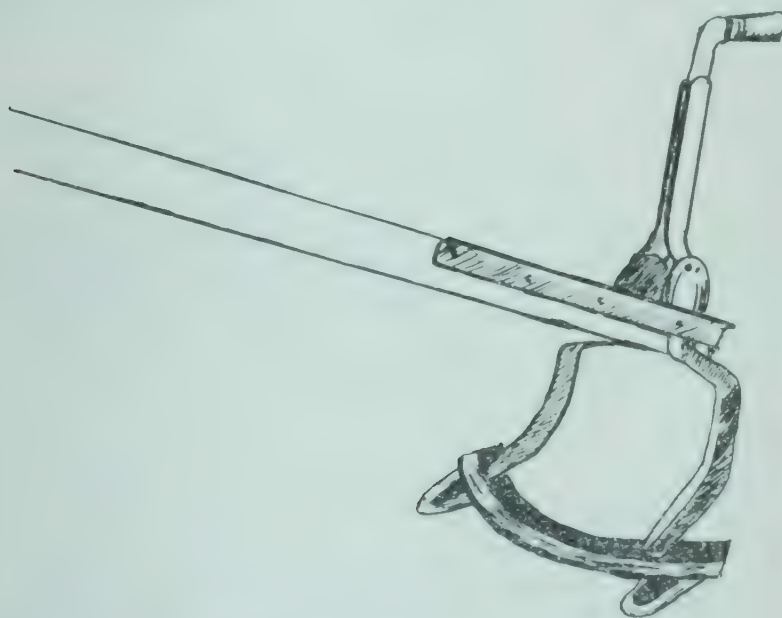


Fig. 26. *Guntaka* (Used in Madras)

Normally, the black soils are ploughed once in three or four years and the ploughing is done with the *desi* ploughs of a slightly heavier build. This is enough to keep down ordinary weed growth and to break the hard pan, if any. For the ploughing of the black soils infested with deep-rooted weeds, large-

sized, heavy wooden ploughs, drawn by four or five pairs of bullocks, are employed. Large iron ploughs with fixed mould-board and heavy ploughs of the turnwrest type are also used for the same purpose in many localities. These heavy iron ploughs are also worked with five or six pairs of bullocks and they penetrate the soil to a depth of ten to twelve inches, thus removing the deep-rooted weeds. In recent years, clearance of weedy lands has been carried out by tractors drawing three or four-bottomed, heavy, mould-board or disc ploughs, which penetrate the soil to a depth of twelve to fifteen inches. The high price of tractors and tractor implements puts them entirely beyond the pockets of ordinary small farmers. The Central and some of the State Governments have set up special organisations equipped with heavy tractors and tractor implements for land reclamation on custom. The preparation of ridges for the ridge-sown crops is carried out by manual labour using shovels, or with double mould-board ploughs. Sometimes the ridges are prepared with a *desi* plough, having a triangular wooden piece wedged in between the plough share and the yoke pole. The plough cuts through the land and the wooden attachment throws the earth on either side of the plough furrow. In the return operation, another furrow is opened along side at the desired distance, the space between the two furrows forming a crude ridge. These crude ridges are later set right by manual labour (Fig. 27).

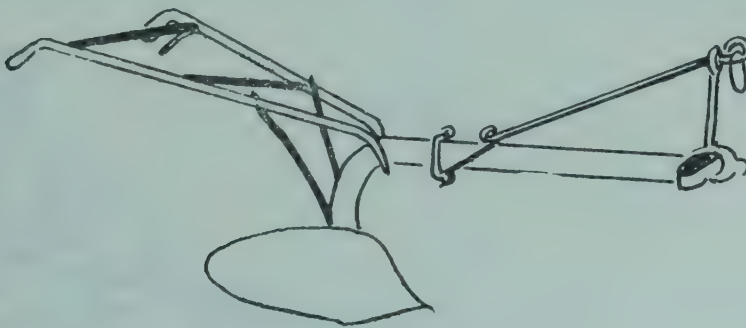


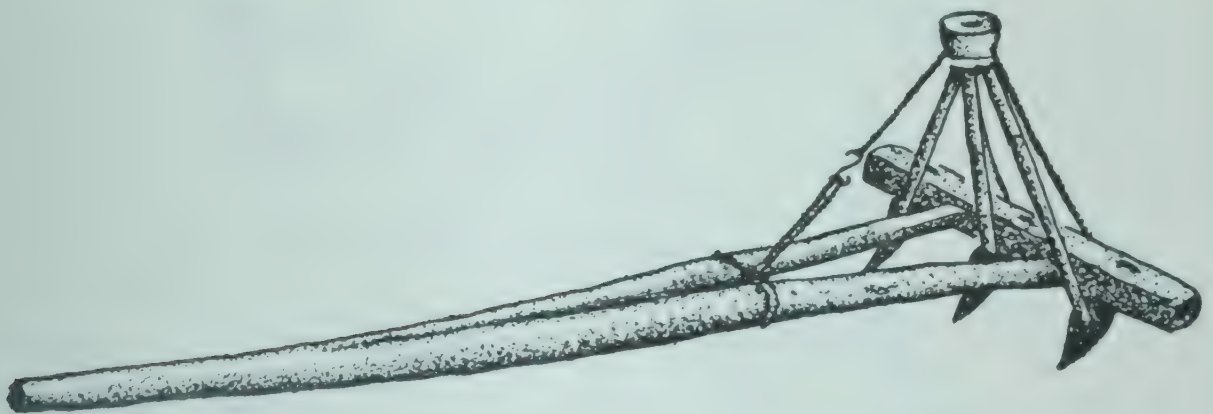
Fig. 27. 'Victory' Mould-Board Plough

The implement in general use for sowing the seed in lines in the black cotton soil tracts is the simple appliance called *mogha*, *sarota* or *sadde*. This one-row drill consists of a single bamboo tube, about three to four feet in length and one-and-a-half or two inches in diameter (Fig. 28). The tube is fitted at its upper end with a perforated wooden bowl into which the seed is fed. The *mogha* or *sadde* is fastened by a rope to a blade harrow and guided by a woman along the furrow made by the edge of harrow blade. In Mysore and Khandesh tract of Bombay, two separate *moghas* are fastened to a *dufan* (two-row drill), one behind each coulter, and these are guided by a woman along the furrow made by the coulter. The women follow about four to five feet behind the drill and pour the seed into the bowls of the *moghas*. When



Fig. 28. Single Row Cotton Drill

sowing in this manner, the tubes and the bowl of the two-row drill are removed and the drill is used only to open furrows in which the seed is dropped as explained above. In some parts of Malwa (Madhya Pradesh), the crop is sown with an implement called *nai*, which is a *desi* plough with a bamboo tube attached to it, through which the seed is dropped in the furrow made by the plough. Indigenous drills with two or three tubes are also commonly used for sowing the cotton seed. These country drills, called *dufan*, *phadak*, *tiphon*, *gorru* or *gorrukalappai*, consist of a beam fitted with two or three tines resembling little ploughs, each of which has a hole running through it (Fig. 29).

Fig. 29. *Tiphon* (Three-Coultered Seed Drill)

Into these holes are fitted bamboo or metal tubes, the upper ends of which meet in a wooden or metallic bowl. When the implement is driven across the field, the seed fed into the cup falls down the tubes and drops into the small furrows made by the little ploughs. These simple, indigenous drills have been in use for centuries past and have been found satisfactory in operation and well-suited to the available, small-sized draft animals. However, it may be mentioned that these country drills do not possess any device for regulating the distance between plants in the rows. The spacing in the rows is controlled

by adjusting the speed of dropping the seed in the bowl of the drill. The more complex two-row cotton planters imported from abroad and their local adaptations have been recommended in some parts of the country in recent years but very few farmers have taken to them so far.

For the weeding of the crop, hand hoes of different types are used. In the Punjab, the broadcast crops are given hoeings with the *kasaula*. Like the Egyptian *fass*, it consists of a triangular iron blade, having four to five inch sides, three to four inch base and a long bamboo handle. This implement not only removes the weeds but also loosens the soil. The implement used for the same purpose in Uttar Pradesh and in the black cotton soil tracts in central, western and southern India, is a small sized, triangular or sickle-shaped hand hoe known as *khurpi* (Fig. 30). The bent blade of the *khurpi* has a sharp edge, which penetrates the soil easily and uproots the young weeds.

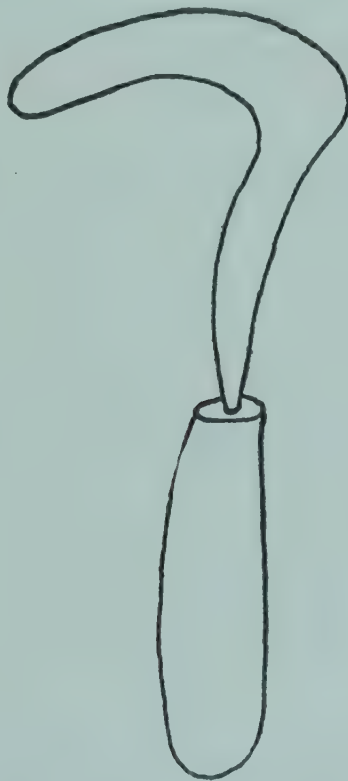


Fig. 30. *Khurpi* (Hand Hoe)

For the hoeing of the row crops in northern India, the light *desi* plough and an implement called the *triphalli* are commonly used. The *triphalli* has three bent, iron tines attached to a wooden log which is provided with a handle and a yoke pole. The width of the implement is adapted to the spacing between the successive cotton rows. In the black cotton soil tracts in central and southern India, the hoeing is done by bullock hoes, called variously *kolpa*, *dauri*, *daura*, *yade kunte* and *danthulu*. This implement resembles the blade harrow but is much smaller than the latter. Its blade is only six to ten inches in

length and one to one-and-a-half inches in width. It is so light that generally two and sometimes three of them are attached to the yoke for one pair of bullocks. Each implement, however, is guided by a separate person in adjacent inter-row spaces. In some part of Khandesh in Bombay, a *daura* with a slit blade is used. The half blades in this case work on either side of a row of plants. The *kolpa* or *daura* can be used easily in the early stages of the crop but as the plants grow tall, the wooden beam to which the blade is attached causes physical damage to them. To overcome this difficulty, another implement called the 'Indore Ridger' is used for hoeing the crop in some parts of Malwa in Madhya Pradesh. This implement has a short beam with sloping ends. The working part of the share is attached to the beam by a strong bent iron bar. The Ridger can be used in the cotton crop even up to the flowering stage. It not only eradicates weeds but also produces a good mulch, cuts shallow furrows between crop rows and earths up the plants. The furrows carry away excess rain water which would otherwise damage the crop. Like the *daura*, two or three ridgers can be operated by one pair of bullocks, thus expediting the operation and lowering its cost. Planet Junior hand hoes are used for the harrowing of experimental crops at the Government Research Stations, and bullock-drawn hoes of the same design are used by some of the well-to-do progressive farmers (Plates V and VI).

The harvesting of the crop in all parts of the country is done by manual labour, mostly by women and children. Mechanical harvesters are not in use anywhere.

The separation of fibre from seed is done by power-operated ginning machines. Only in some villages in the interior a small portion of the produce is ginned by means of hand-operated wooden *charkha gins*. In recent years, improved models of hand gins were designed and introduced in some parts of the country by the All-India Village Industries Association, but they have not found much favour with the farmers as yet.

PREPARATION OF SOIL

For conserving soil moisture and securing good germination of seed and optimum growth of the plants, proper preparation of land is as necessary as the selection of a suitable soil. The cultural operations comprising the preparatory tillage vary with the crop, the nature of the soil, the previous crop grown, the season of growing, the system of cultivation and the weather conditions prevailing in the period prior to sowing. The methods of preparing land for cotton in India have evolved from the accumulated empirical experiences of farmers who have grown the crop for centuries. Though rarely based on the results of research and investigation, the traditional practices appear to be fairly well suited to the prevailing environmental and economic conditions. However, the most outstanding feature of the preparatory tillage is that it is carried out hurriedly in most of the cotton tracts. For one thing, the period

between cotton sowings and the harvest of the preceding rotation crop is generally short and almost fully taken up by threshing operations. For another, the soil during this intervening (usually rainless) period is so dry and hard that a thorough or deep cultivation with the available implements and draft animals is very difficult. In many areas growing rainfed cotton, soil cultivation can be started only after an odd shower of rain in the hot weather or after the monsoon rains have commenced, i.e., only a few days ahead of the optimum sowing season. Every effort is then made to secure a pulverised surface by light cultivation in as short a time as possible. The short sowing season also makes an expeditious preparation of soil incumbent. Every heavy shower at this time causes delay in the sowing of the crop and if there are incessant rains, the sowing may have to be abandoned, or the sown crop may have to be replanted after a break in the rains sets in. Light preparatory cultivation is considered adequate for the cotton crop. It is a common belief that an ideal seed bed for cotton is formed if the soil is loosened and pulverised to a depth of three or four inches, kept free of weeds and compacted with a wooden beam (*sohaga*) or an inverted blade harrow before sowing. Too much cultivation for cotton is not considered to possess any special benefits. Land, therefore, is left uncultivated after the previous crop. Even the stubble is not removed for a long time.

In the Punjab, eastern part of Bikaner and western districts of Uttar Pradesh, where the major portion of the cotton crop follows a crop of wheat, the interval between the harvest of the cereal crop in March or April and the sowing of the irrigated crop in April or May is very short. Threshing of the *rabi* crop also takes place during the same period. The result is that the preparation of land for the irrigated cotton crop is very hurried. The soil is given a heavy irrigation (*rauni*) and one or two ploughings with the *desi* plough or light iron ploughs. It is irrigated lightly immediately thereafter, ploughed once again, sown with cotton and planked with a wooden beam to compact the soil. Under these conditions, the inadequacy of the preparatory tillage is very often made good by a more thorough and repeated interculture in the growing period of the crop. In some parts of Uttar Pradesh, where the wheat crop is harvested somewhat earlier, the soil is more thoroughly pulverised. The unirrigated crop which is generally sown early in July in these tracts is usually given one additional ploughing. Unlike Egypt, all cotton is sown on level flat beds even when it is grown under irrigation. Ridging of land and sowing cotton on ridges is not adopted except in some experimental plots at Government Research Farms. Though the furrows between the ridges economise the use of irrigation water, the cost of ridging is high and there is no adequate increase of yield on ridged lands.

In the black soil areas of Rajasthan, Madhya Pradesh, Bombay, Andhra Pradesh, Mysore and Madras States, land is given a ploughing once in four or five years to keep down weed growth. If the soils become heavily infested

with deep-rooted grasses like *hariali* (*Cynodon dactylon*) or *kunda* (*Cyperus rotundus*), the weeds are either dug out by hand labour, using crow bars and pick axes, or removed by deep ploughing. The deep ploughing is done with large, heavy, wooden ploughs of the pattern of the small *desi* plough or with heavy iron ploughs with fixed mould-boards. In some localities, turnwrest ploughs are used for the same purpose. All these heavy ploughs are worked by four or five pairs of bullocks. In recent years, large areas of land infested with *kans* (*Saccharum spontaneum*) in the States of Madhya Pradesh and Uttar Pradesh have been cleared by tractor ploughing. The land clearance operations are carried out in the dry season from October to May, when the soil is usually in good condition for deep ploughing. Experiments conducted at Indore in Madhya Pradesh, have shown that the noxious *kans* can be controlled effectively by hoeing the infested land weekly or every ten days with a blade harrow in the dry season from November to May. Repeated hoeing damages the underground parts of *kans*, thus greatly reducing the infestation.

When cotton follows *jowar* (sorghum) or Bullrush millet (*Pennisetum typhoides*), the stubble of the cereal crop is removed by harrowing two or three times with a blade harrow after finishing threshing operations. The stubble is then collected and burnt in the field or used as fuel. After the harvest of the *kharif* or *rabi* cereals, the black cotton soil gradually loses moisture, bakes hard, develops deep cracks, and crumbles in the hot weather. The ploughing or harrowing of such hard baked lands is ordinarily not feasible. The cracking of the soil in the hot weather has an effect somewhat similar to that of ploughing. Fissures cause the soil to crumble and become loose on the surface. That is why an annual ploughing of the black soils is considered unnecessary. It is commonly said that the black cotton soil ploughs itself. On the other hand, the condition of the soil after the harvest of groundnut or *lang* (*Lathyrus sativus*) is much better than what it is after the harvest of cereals. Groundnut is harvested by either harrowing or ploughing the land. Both of these operations leave the soil clean, relatively loose and capable of being harrowed easily in summer months in preparation for cotton. The running of the blade harrow two or three times across the field produces a fairly good tilth. The preparatory tillage in these instances is easy, expeditious and less costly. This is one of the reasons why the cotton crop following groundnut gives a higher yield than it does after a crop of cereals. Growing of cotton after groundnut in the rotation is, therefore, recommended in many States.

The usual method of preparing land for rainfed cotton in the black cotton soil tracts is to stir up the soil with a *bakhar*, *dodda kunte* or *guntaka* (blade harrow). This implement penetrates the soil to a depth of three to four inches and produces a fairly good tilth for the sowing of the seed. For crops sown in June or July, harrowing is started after a shower of rain in the hot weather (March to May) or immediately after the commencement of the south-west monsoon in June. Three or four harrowings are usually given to obtain a good tilth.

With one blade harrow operated by a pair of bullocks, three to four acres of land can be prepared in a day for the sowing of the crop. The expeditious completion of sowing on the black soils is necessary if undesirable results of late sowing due to heavy showers of rain are to be avoided. In the case of rainfed American cotton in Mysore, preparatory tillage is designed to conserve rain and soil moisture. Immediately after the harvest of the rotation crop, the land is ploughed several times, failing which it is worked repeatedly with a heavy blade harrow. Every attempt is made to keep the soil surface loose and secure a good tilth. In Madras, the cultivation of the land to be sown with unirrigated cotton in September or October is started with the commencement of the monsoon rains in July and three or four ploughings are given to secure a satisfactory seed bed. The character of the rainy season in this tract and the later sowing season of cotton permit a more thorough preparation of land by ploughing. It also enables the farmer to plant his crop at the optimum sowing period. Broadly speaking, for the good growth of cotton plants on the deep black soils, three things besides initial soil fertility are usually necessary: (i) the soil should be free from injurious weeds; (ii) it should possess adequate moisture in the surface layers for the first few weeks after sowing; and (iii) it should be provided with good surface drainage thereafter to prevent water-logging. It has been observed that an initial construction of small field bunds at suitable distances to facilitate absorption of the first six to eight inches of rain, and the subsequent breaking of bunds at suitable points to permit a free flow of excess rain water produce good crop yields. Large tracts of the black cotton soil in Bombay-Deccan and adjoining parts of Karnatak are subject to scanty rainfall as well as erosion. Bunding of individual fields at their lowest points and the provision of weirs for surplus water has been fairly common in these areas. During the past 10 years, however, large scale construction of contour bunds has been carried out. Furthermore, contour ploughing in bunded lands has been found beneficial but it has not yet become a common practice.

Red soils in the Peninsular and southern India retain but little moisture in the post-monsoon season. They are almost always planted with only rainy season rotational crops, such as *jowar*, *bajra* (*cumbu*), other millets, pulses, castor, early groundnut, sesamum, etc. After the harvest of these crops in October-November or later, the soil becomes very hard and practically unworkable. Cotton grown on these soils in the following monsoon is given only two or three harrowing as preparatory cultivation. The harrowing is commenced after first good monsoon rain. If there are any summer showers, the soil is ploughed once in addition. The land for irrigated cotton is given a watering, ploughed once and harrowed twice or thrice. In Madras, however, usually four ploughings are given to ensure a really good tilth.

In the hill tracts of Assam, cotton is grown on steep hill slopes. The tribesmen occupy plots of slopy forest land in the dry season from January to March,

fell down the trees, cut the undergrowth and set fire to the cut wood. When the land has thus been cleared, it is prepared by crude hand hoes for sowing the crops. The working of bullock-drawn implements on the hill slopes is not ordinarily practicable. Any deeper working of the soil, unaccompanied by anti-erosion measures, in these hill tracts, does more harm than good. The construction of contour bunds (embankments), at suitable intervals across the slope, and planting of kudzu vine or other similarly suitable trailing plants above the bunds is advocated. Terracing of fields has also been taken up in some localities. In view of the highly destructive and wasteful present method of preparing land for cotton, terracing of hill slopes needs to be given all possible encouragement.

The foregoing account shows that in the matter of soil preparation, the cotton farmers in the different parts of India are guided largely by the type of soil, the system of cultivation and the character of weather prevailing in the interval between the sowing of cotton and the harvesting of the crop preceding it. Commonly, only light preparatory tillage is practised. Occasional deep ploughing is done on the black cotton soils either to break the hard pan formed by the repeated use of the blade harrow, or to eradicate noxious weeds like *hariali*, *kunda* or *kans*. This is in accord with the results of the tillage experiments conducted in India, as well as other countries, where it has been found that shallow tillage gave usually as good cotton yields as deep ploughing or even sub-soiling. Deep cultivation in hot dry tracts encourages loss of moisture as well as organic matter from the soil. More frequent tillage than is really necessary is also said to produce the same adverse effects. For irrigated cotton, the land is usually given a preparatory flooding and ploughed two or three times to secure a good tilth.

METHOD OF SOWING

The two common methods of sowing cotton in India are broadcasting the seed and sowing it in suitably spaced rows. The dibbling of seed by hand is practised only in some parts of Mysore, Madras and Assam or by the Government Research Farms in sowing experimental or seed multiplication crops. Dibbling is a slow and costly process. Ordinarily the saving in the quantity of seed sown by dibbling is not adequate to set off the higher cost of the labour involved. Moreover, when large areas have to be planted quickly in order to complete the work under favourable conditions of soil moisture, the less expeditious method of dibbling does not serve the purpose.

In the Punjab and the adjoining parts of Bikaner and Uttar Pradesh, cotton is usually sown broadcast. After broadcasting the seed, the land is ploughed and planked. In broadcast sowing, a high seed rate has to be used. Not only this but also the seed is not sown well distributed or at a uniform depth. This results in defective germination of seed and a highly irregular stand of plants, which in turn, not only inhibit the use of bullock-drawn imple-

ments for hoeing the crop but also affect plant growth and yield adversely. Because of these disadvantages of broadcast sowing, the Agricultural Departments of these States have in recent years been advocating the sowing of the crop in lines. Some cultivators practise this method by dropping the seed by hand in shallow furrows made by the *desi* plough, whereas others do so with the help of two or three-coultered indigenous seed drills. Line sowing has become fairly popular in Uttar Pradesh, but the area thus sown is still rather limited. The practice, therefore, needs to be encouraged vigorously. This will ensure the placing of seed at proper depth, a more uniform germination, regular stand of crop and better yield. It will also permit the use of bullock-drawn implements for post-sowing interculture, thereby making the operation easier as well as less costly.

In the black cotton and red soil tracts of central, southern and the Peninsular India, the crop is usually sown in lines on flat land. However, the cultivators of some parts of Telengana and Tamilnad still practice broadcast sowing. In certain black soil tracts, the line sowing is done by dropping the seed by hand in furrows behind a country plough or a blade harrow. When sown in this manner, the seed is usually covered by running an inverted blade harrow (with handle removed) or a log of wood over the sown field. Most of the farmers in the other areas sow the crop with the single-coultered wooden drills called *sarota* in Hindi, *mogha* in Marathi or *sadde* in Kanerese. As stated earlier, it is usually operated behind a blade harrow or a *desi* plough. The use of two or three-tined drills called, respectively, *dufan* and *tiphan* or *gorru*, is fairly common. The distance between the tines corresponds to the inter-row spacing adopted for the crop. In Madras, the planting of irrigated Cambodia cotton on ridges is practised by some farmers. The seed is dibbled by hand on ridge tops. The ridge sowings effect a considerable saving in the quantity of seed as well as irrigation water.

In certain localities growing American cotton in Mysore, it is customary to use the seed drill only as a furrow opener. The drill is run along the length of the field and then across, making shallow furrows in a chess-board fashion, two-and-a-half to three feet apart in either direction. The seed is then dibbled by hand at the points of intersection of furrows at the rate of three or four seeds in each hole, and covered by drawing a light *kunte* or blade harrow over the sown field.

The seed of most of the cotton varieties, and particularly of American types, is covered by short fibre called 'fuzz'. The fuzz makes the seeds cling together, thus hampering their free passage through the bowls and tubes of the indigenous seed drill. For facilitating sowing, it is necessary to separate the seeds by some treatment. The method commonly adopted for this purpose in most parts of the country is to rub the seed with mud, or a mixture of earth (or ash) and fresh cow-dung. By this treatment, the fuzz on each individual seed becomes pasted on the seed itself and the seeds no longer cling to each

other. After rubbing, the seeds are usually dried in the shade for a while. The separation of seeds makes broadcasting also easier. Furthermore, by making the fuzz adhere to the seed, the treatment brings the latter in closer contact with moist soil, thus helping quicker germination. In some parts of the United States of America, the fuzz is sometimes removed from the seed by chemical methods. The seed is treated with strong commercial sulphuric acid, which burns the fuzz, or with chloride of zinc, which dissolves the short fibre. In the case of sulphuric acid treatment, the seeds are soaked for two minutes in it, then taken out and washed in running water to remove the chemical. In the case of chloride of zinc treatment, the seeds are immersed in its solution for ten to fifteen minutes and then washed. The chemical treatments not only remove the fuzz, but they are also said to improve the germinating capacity of the seed, hasten germination and make for easier handling of seed. However, these processes are not only costly but also have to be used with caution to avoid injury to the seed. They are, therefore, not recommended.

In the Punjab and Uttar Pradesh, where the cotton crop suffers commonly from pink bollworm (*Platyedra gossypiella*), seed stocks generally contain many 'double seeds', in which the larvae of this pest hibernate, during the cold season. On return of favourable weather conditions, the hibernating larvae emerge and attack the new crop or the alternative host plants. The heating of seeds to a temperature of 60°C. kills the larvae in the 'double seeds'. Hence, some cultivators expose their seed stocks in a thin layer to direct sun for a few hours during the hot months of April and May.

For a uniform stand of plants and heavy yield, a good and quick germination of seed is essential. The soaking of *desi* cotton seed for two or three hours and that of the fuzzy American varieties for four to six hours in water before treatment with mud and cow-dung, hastens germination and thereby gives a better start to young seedlings and also ensures a more uniform stand of plants. The soaking of seed before sowing is a common practice in many parts of the country but where it is not so, it should be advocated for both irrigated and rainfed cottons. The benefits are more pronounced in the case of American varieties and the resowing of gaps in a rainfed crop. Insect-damaged and immature seed floating on the surface of water is removed and discarded. Sowing is preferably to be carried out in the early hours of the morning. There is usually more moisture in the soil at this time than during the remainder of the day.

As mentioned already, the crop grown on the hill slopes in Assam is sown by dibbling the seed. After the land has been cleared of forest growth, shallow seed holes are prepared by blunt wooden sticks and a handful of a mixture of seeds is put in. This mixture is made up of paddy, millets, maize, cotton, pulses and vegetable seeds. Very often, cotton seed is sown after the paddy,

pulse, vegetable and other seeds have completed germination. In this case, cotton seed is dibbled in the interspaces between the seedlings of other crops.

The dibbling of seed at the Government Farms is also done by hand. The seed holes are made by blunt wooden sticks or by using special dibblers. The dibbler usually consists of a wooden plank ten to twelve feet long, three to four inches wide and about one inch thick. The plank is fitted with a series of suitably spaced, blunt, conical wooden pegs. When the plank is placed pegs downward on moist soil and trampled by feet, the pegs penetrate into the soil. On being removed, the dibbler leaves a row of properly spaced seed-holes of uniform size and depth. The size of the pegs depends on the depth at which the seed is required to be placed. One or two seeds are sown in each dibble, depending on the availability of seed. In order to secure an unbroken and as large a stand of plants as possible from a very small quantity of valuable seed, the seed sown in the dibbles is covered by sand and hand-watered. This prevents the formation of crust on the sown seed and helps the emergence of seedlings above ground. Under conditions of intensive cultivation, the dibbling of seed produces very good results by securing a uniform stand of properly spaced plants. This should be recommended particularly in tracts in which the sowing of the crop is not necessarily to be completed in one or two days but can be spread over a longer period. Dibbling also produces good stand of plants under conditions of different soil management.

SEED RATE AND SPACING

The optimum number of plants per acre, and the distances separating the plant rows as well as the plants in each row depend on the inherent vegetative habit of a variety and conditions of soil fertility, soil moisture and cultural practices. For instance, the optimum number of plants per unit area in the case of a highly branching, monopodial variety is much less than that in the case of a non-branching, sympodial type. Similarly, under conditions of good plant growth, such as, greater fertility of the soil, availability of irrigation facilities and early sowing, the number of plants per unit area (particularly of varieties having tall, vigorously branching plants) has of necessity to be smaller than on relatively poor soil, or under late sowing and unirrigated conditions in which the plants do not make a vigorous growth and the per plant yield is relatively low. In the case of dwarf non-branching varieties, on the other hand, close spacing gives the best results even on rich soils.

The optimum number of plants under different conditions varies widely and has to be secured by judicious variations of spacing and seed rate. In working out proper seed rate for a variety for a given set of environmental or cultural conditions, due allowance has to be made for the spacing adopted, the seed size, the germination capacity of the seed and the mortality of the plants caused by diseases, insect pests, vagaries of the season and physiological derangements. In the case of American cotton, the relative fuzziness of the

seed has also to be taken into account. However, it may be stated that in actual practice, most of the cotton growers do not adjust the seed rate to the optimum number of plants suitable for a given environment. Also no attempt is made to regulate the number of plants by sowing in properly spaced hills or by thinning the plant in the rows. The cultivators invariably use a relatively heavy seed rate to provide against failure of germination and mortality of young seedlings due to disease or other natural calamities. A larger number of seeds is also believed to help the emergence of seedlings through surface crust.

Depending on the various factors enumerated above, the seed rate and spacing of the crop differ from tract to tract and sometimes even in the same tract. In the irrigated areas of the Punjab and Bikaner, 8 to 10 pounds of seed is sown in the case of *desi* varieties and 10 to 12 pounds in the case of American types having somewhat larger seeds. With the introduction of American varieties possessing more heavily fuzzed seeds, the need for a still higher seed rate has arisen. Accordingly, the Departments of Agriculture have of late recommended a seed rate of 16 to 20 pounds per acre for such types. The seed rate for *desi* cotton under rainfed conditions in these tracts ranges from 10 to 12 pounds. As already stated, much of the crop in this zone is sown broadcast and line sowing is a recent introduction. In line sown crops, the adjacent rows are spaced two-and-a-half to three feet for *desi* cotton, and three to three-and-a-half feet for American cotton. This spacing is usually given regardless of the variations in soil fertility and the date of sowing. It is only the intelligent farmers who make due allowance for these factors and adopt a wider spacing in the case of more fertile soils, and closer spacing when the crop is sown rather late in the season or is grown on rather poor soil. Late sown crops and those grown on less fertile soils have to make up the deficiency of yield by a greater number of plants per acre.

In Uttar Pradesh, the *desi* variety forms the bulk of the crop. The seed rate varies from 12 to 16 pounds per acre. This relatively high seed rate is necessitated by the heavy damage caused to the seed by pink bollworm. The seed obtained from the ginning factories practically always contains 20 to 25 per cent., and sometimes more, of insect-damaged or broken seed unfit for sowing. In the case of American cotton, a seed rate of 16 to 24 pounds per acre is commonly used. The seed of American varieties is much bigger than that of indigenous cotton. One hundred American seeds weigh eight to twelve grams as compared with only five to seven grams of an equal number of *desi* seed. The American cotton is sown in lines, spaced two-and-a-half to three feet whereas the *desi* variety is usually sown broadcast. A change over to the sowing of the *desi* variety in lines will not only reduce the seed rate but will also make the interculture of the crop easier as well as cheaper. Interculture with bullock hoes, which is not feasible for broadcast crops, is the usual practice for crops sown in lines.

The black cotton soil tracts of Rajasthan, South Uttar Pradesh, Madhya Pradesh and Maharashtra largely grow non-branching, early maturing, sympodial types of *arboreum* cotton. The soils are not very fertile and the rainfall is highly fluctuating. A relatively high seed rate is, therefore, used in these areas. The seed rate in these States varies from 12 to 16 pounds per acre; in some localities it goes up to even 20 or 24 pounds. The crop is sown in lines and the distance between the adjacent rows varies from 12 to 18 inches. In North Mysore and Rayalaseema districts of Andhra Pradesh, early maturing types of *herbaceum* cotton are grown in the black soil, and a mixture of *arboreum* varieties on the red soils. Both these types are non-branching and sympodial. Moreover, the rainfall of this tract is relatively low and highly uncertain. The cotton plants rarely attain a large size; they usually remain short statured and spindle-shaped in appearance. The crop in these tracts is, therefore, sown relatively closely and a high seed rate is employed. It is sown in lines 10 to 14 inches apart, and the seed rate varies from 16 to 24 pounds per acre. In an investigation conducted recently in Madras State to study the effect of different spacings on crop yield, it was found that a spacing of three inches between plants in the row gave a higher yield than six or nine inch spacings. This confirms the advantages of close spacing of cotton in this tract.

In Gujarat on the West Coast, the annual rainfall varies from 40 inches in Surat to about 25 inches in Ahmedabad and still less in the districts north of it. The soil fertility also declines from south to north. In accordance with these declining trends in rainfall and soil fertility, bushy, monopodial *herbaceum* varieties are grown in the South and central Gujarat and early maturing, less branching, closed-boll types in North Gujarat. The entire crop in this tract is sown in lines, but in accordance with differences of varietal characters, rainfall and soil fertility, the crop rows are placed five feet apart in Surat, four feet in Broach and Baroda and only three feet or less in Ahmedabad and the districts further north. The seed rate also varies from 10 to 16 pounds per acre in the same geographical order. The beneficial effects of the wider spacing, practised in Surat have been confirmed by the results of spacing experiments conducted at Surat in recent years (Plate VII). The results of these experiments showed that wide spacing (16 square feet per plant) gave higher yield than closer spacings of nine or four square feet per plant. In Saurashtra, where the conditions of soil and climate are similar to those in the adjoining districts of North Gujarat, the seed rate ranges from about 16 pounds in the south to 20 pounds in the north.

In South Madras and the coastal tract of Andhra Pradesh, rainfed cotton (particularly the mixed crop) is generally sown broadcast, adopting a seed rate of 12 to 16 pounds per acre. In the northern districts of Madras, however, such cotton is sown in lines with *gorru* or the country drill, the distance between the successive rows of the crop being about 27 inches. The seed rate for the line sown cotton is slightly less than that for the broadcast crop, i.e., 10 to 14

pounds per acre. The irrigated cotton in this State is sown either broadcast or hand-dibbled on ridges, which are generally spaced 30 inches apart. The seed rate for the ridge sown crop varies from 6 to 10 pounds per acre whereas that for the broadcast crop ranges between 10 and 15 pounds.

In Mysore, sowing in lines is the general practice. The rows of *desi* cotton are 18 inches apart in tracts of poor rainfall and 24 to 30 inches apart in areas of somewhat heavier precipitation. In the case of American cotton (*doddahatti*), a wider spacing (i.e., three to three-and-a-half feet) is given between the rows. The seed rate for *desi* cotton ranges from 12 to 16 pounds per acre and that for the American varieties, from 10 to 12 pounds. Under irrigation, the seed is dibbled by hand at distances of 9 to 12 inches in rows, two to two-and-a-half feet apart. In some places, the seed of American cotton is dibbled by hand at the points of intersection of furrows made crosswise by an ordinary country drill at two-and-a-half to three feet distance. The seed rate in this case is only about eight pounds.

In Assam and Tripura, cotton is grown chiefly on hill slopes and, as indicated already, the seed is dibbled by hand. Rainfall in these hill areas is usually high and it is often received in showers of great intensity. This causes great damage to the freshly sown seed as well as to the young plants. The farmers usually put in a handful of cotton seeds in each seed-hole and space the plant rows relatively closely.

Generally speaking, a seed rate of 12 to 16 pounds per acre for line sown, rainfed crops of *desi* cotton of sympodial habit and a spacing of 12 to 18 inches between rows seem to be the optimum practice for a large part of the country. For monopodial *desi* varieties and vigorous growing American types and for crops grown under irrigation, a spacing of three feet or more between rows gives the best results. In the case of crops sown on ridges, the most appropriate distance between ridges seems to be two-and-a-half feet for American cotton. In ridge sowings, the seed is always dibbled. The sowing of four or five seeds per hole and leaving ultimately two plants per hole usually gives better yield than using more seed or leaving one plant per hole does.

In the case of mixed cropping, the seed rate for cotton has to be adjusted according as the cotton crop is the main crop or a subsidiary one. In line sown mixed crops, the rows of plants may be placed at 15 inch intervals or more according as the cotton variety in the mixture is sympodial or monopodial in habit. In the mixed crops sown broadcast, the stand of plants is determined, in addition by the size and relative quantities of the seeds of crops included in the mixture.

In intercropping, the seed rate for cotton is not materially reduced if the rows of the subsidiary crop are placed at relatively long intervals. The cotton crop on black soils in Peninsular India is usually intercropped with *tur* (*Cajanus indicus*). One row of *tur* is planted after every eight or ten rows of cotton. The seed rate and spacing for cotton in such crops are practically

the same as for pure crops of cotton, i.e., about 12 to 16 pounds per acre. When cotton is grown as a subsidiary intercrop, its rows are placed at much longer distances, and only a small quantity of seed (say three to four pounds per acre) is used. The seed rate is still less if the seed is dibbled by hand instead of being sown through a drill. The growing of cotton and chillies together in some parts of Madras and Andhra Pradesh is an instance of this nature.

Cotton seed can remain viable for several years, but the proportion of seeds retaining viability under ordinary conditions of storage decreases with the passage of time. Therefore, generally speaking, seed more than one year old is not used for sowing. When due to crop failure or other reasons new seed is not available and old seed has to be used for sowing, the seed rate per acre is increased suitably to allow for a lower germinating capacity.

Given satisfactory germination of seed, the use of a relatively high seed rate in sowing ordinarily secures a good stand of plants. However, sometimes due to faulty drilling or death of young plants caused by attacks of insects or fungi soon after sowing, the crop-stand becomes patchy and irregular. In the tracts, growing rainfed cotton, the rains immediately following the sowing of seed are sometimes of such great intensity that the sown seed or the young seedlings are washed away. In such cases of irregular or ruined stands, the cultivators carry out a partial or general resowing. General resowing is fairly common in South Gujarat of Bombay State. When a field has to be resown completely, it is ploughed or blade-harrowed and planked to secure a good tilth as for the first sowing. The pre-sowing treatment of seed, and the method of sowing are also similar. Only the seed rate is increased a little to ensure a closer stand as in the case of late sowing. In partial resowing, the seed is soaked in water and sown by hand in holes or shallow furrows made by a blunt stick and covered with moist earth. In Madhya Pradesh, the gaps are sometimes filled with dibbled *jowar*. When the gaps in the rows are long, or when a whole row needs resowing, the *mogha* dragged by a man-labourer is used for redrilling the cotton seed. Resowing in the case of irrigated cotton is usually only partial. Reseeding in this case is done by hand and the re-sown patches are hand-watered.

It may be pointed out that, generally speaking, the growth of plants in the rows is very thick owing to a heavy seed rate and no thinning. Death of a few plants, whatever the cause, is ignored or considered only the nature's way of reducing over crowding. Such natural thinning affords to the remaining plants a chance for better growth, particularly if the variety cultivated has a good branching habit. The small gaps are covered up by more vigorous growth of plants and the crop yield does not suffer. In some cases, it may actually benefit. Observations made in different parts of the country showed that resowing of gaps aggregating up to 20 per cent. of the stand did not increase the yield. Patches of this degree can be safely ignored, particularly if the

variety is a monopodial type and the optimum sowing season has almost passed. In the case of varieties with single stalk plants, resowing done in the early part of the growing season is of some use. In their case, the total number of plants per unit area has a very significant effect on the yield of the crop. It has also been often observed that resowing rather late, say four to five weeks after the original seeding, is not of much benefit. The plants from such late sowings do not make good growth and seldom produce a normal crop. Even plants from resowings done only 10 to 15 days after the first sowing rarely catch up with the earlier sown plants. They remain stunted and produce very few or no bolls.

CULTIVATION AFTER SOWING

In many States, cotton is grown predominantly as a rainfed crop, sowing being done at the commencement of the monsoon season. Large number of seeds come up in the fields simultaneously with the emergence of the seedlings and compete with them for plant nutrients. Cotton is very sensitive to this competition and suffers greatly if the weeds are allowed to establish themselves, while the plants are still young. In years of incessant rains soon after the completion of cotton sowings, weed removal becomes difficult. In such seasons, the weeds make rank growth and very nearly smother the cotton plants. Similarly, fields infested with deep-rooted grasses, such as *hariali*, *kunda* and *kans* become virtually unfit for cotton growing.

To lessen the competition from annual weeds, the Indian cultivator usually tries to keep the fields clean and covered with a thin layer of loose soil by inter-row cultivation of the standing crops. The first interculture is practically always a manual operation which ensures a complete removal of weeds at a very early stage of crop growth. Subsequent hoeings are given whenever weeds reappear or there is a break in the rains. These additional hoeings may be done either by hand or by bullock-drawn implements. Sometimes, repeated hoeing is practised to supplement the somewhat inadequate preparatory tillage. In the relatively drier parts of the country, the crop is hoed oftener to keep the surface soil mulched as a measure of reducing loss of soil moisture through evaporation. In the case of irrigated crops hoeing after every watering, particularly in the early stages of plant growth, is deemed necessary for the same reason.

In the irrigated crops sown broadcast in the Punjab and Bikaner, one or two hand hoeings are given with the *kasaula*. The hoeings are thorough, removing all the weeds and leaving a shallow mulch about two inches thick. A thorough weeding of the crop as early as possible is considered absolutely necessary. The weeds are not allowed to grow and much less to set seed. There is a common proverb in this part of the country that "one year's seedling is seven year's weeding", implying thereby that if weeds are allowed to grow in any season, it is very difficult to get rid of them for several years. When the cotton plants are about one foot high, a *desi* plough is worked in the inter-

row spaces. This ploughing is usually done just before the beginning of the monsoon rains. It not only opens the soil and thereby ensures good absorption of the rain water, but also produces a partial thinning of the crop. In the crop sown in lines, hand-weeding is done only once when the plants are very young. This is followed by two or three harrowings with a three-tined hoe (*triphalli*).

In the central and southern parts of the country, the crops are hand-weeded when the plants are four to six inches in height. The implement used for this purpose is the sickle-shaped hand hoe (*khurpi*). The weeding is done once again, if necessary, otherwise the crop is bullock-hoed three or four times. The bullock hoe (called *kolpa* or *dauri*) is worked between the rows of the line-sown crop, and as stated already, generally two or three of these implements are yoked to one pair of bullocks and operated simultaneously in adjoining rows. This makes hoeing very cheap and expeditious. Two men with a pair of bullocks and two *kolpas* can hoe six acres in a day. In some parts of Malwa, the later hoeings are given with Indore Ridgers which earth-up the plants in the row and form shallow furrows in the inter-row spaces. These furrows permit an easy run-off of the excess rain water.

In South Gujerat where the crop is sown in rows four to five feet apart, the fields are hand-weeded once or twice, and the interculture between the rows is carried out with the blade harrow. The soil is kept scrupulously free of weeds and a shallow mulch one or two inches in thickness is maintained particularly after the cessation of the south-west monsoon. Sometimes in September or October a *desi* plough is worked between the rows as well as between the plants in the row. In this way, the plants are partially earthed-up, and free flow of the excess rain water is facilitated. It is also believed to check cracking of black soil.

In Madras and Mysore, the rainfed crops are hoed four or five times with the small, blade harrows (*yade kunte*), which are practically similar to the *kolpa* or *dauri* used elsewhere in the black cotton soil tract. When cotton is sown checkered, the harrows are operated both along the length of the field as well as across it. Sometimes the interspaces are worked with a *desi* plough before being harrowed. This removes the weeds more effectively. The irrigated crops are practically always hoed by manual labour. The division of the field into small plots for purposes of irrigation hinders the use of bullock-operated harrows. Usually two or three hand-weedings are given to irrigated Cambodia cotton. In Bellary and Dharwar districts of North Mysore, the crop is sown largely on the black soil in August or September, when the south-west monsoon is coming to an end. There is very little rain between then and the harvest season in February-March. The plant growth and maturation of the crop depends almost wholly on the moisture conserved in the soil. From November onwards, the soils start to crack, developing deep fissures and breaking up into large blocks of hard soil. These cracks not only accentuate

evaporation but they also cause injury to plants by tearing as under their roots. The farmers in this tract hoe their crop repeatedly at short intervals to produce a good mulch and fill up the fissures with loose soil to minimise their adverse effects. As many as six to eight hoeings are given in some years.

The beneficial effects of hoeing in normal seasons are largely due to the removal of weeds. Cultivation experiments conducted for several years in Marathwada and some other parts of the country have shown that in seasons in which there are no extraordinarily long breaks in the rains, weeding alone produced as good yields as weeding coupled with hoeing. However, in seasons in which prolonged dry weather intervened between successive falls of rain, weeding combined with hoeing gave the best results. Since the exact course of rain is always unpredictable, the farmers invariably prefer to hoe the crop three or four times at suitable intervals after the operation of weeding.

On specially fertile soils growing irrigated crops, and in tracts of heavy rainfall, the cotton plants sometimes make extra-vigorous vegetative growth and become very tall. To arrest unnecessary growth in such cases and to encourage the development of fruiting branches, the plants are 'topped', i.e., their apices are cut off. Topping, however, is a laborious and costly process, and it is practised only under exceptional circumstances.

As stated already, a deliberate thinning of the crop as a means of regulating the number of plants per unit area or the proper spacing of individual plants in the row is usually not practised. Only in South Gujarat, the crop is thinned, leaving one plant at every 12 to 18 inches distance. In the remainder of the country, excepting the tracts growing cotton on ridges, the crop is kept unthinned. A certain amount of unregulated thinning may take place when interculture is done by bullock-drawn hoes but it is seldom of the desired order. The stand in the rows is almost always too thick. Hoeing between plants in such crowded stands is difficult. The result is that due to over-crowding many plants remain stunted and produce very few or no bolls. This is responsible for a vicious circle. Over-crowding produces unfruitful plants, lowering crop yield, whereas the farmer considers the number of plants thinned, as so much loss of potential production and hence rates the practice undesirable. The irrigated crops grown on ridges are usually planted by dibbling seeds by hand in suitably spaced seed holes. Four or five seeds are sown in each hole, and when the plants attain a height of four to six inches, they are thinned to one or two plants per hole. During the operation of thinning, the weak and off-type plants, if any, are removed and only the more vigorous and type plants are left to continue growing.

The use of chemical weed-killers is unknown at present. A co-ordinated investigation is in progress in many parts of the country for studying the possibilities of employing various herbicides as sprays or dusts before or after sowing for the eradication of weeds. The high cost of imported chemicals and the relatively low crop yields in a major part of the country are likely to prove

obstacles in the way of their large scale use.

MANURING

Under existing methods of cultivation, the cotton crop makes a heavy demand on soil fertility. After the harvesting of seed cotton (*kapas*), sheep, goats and cattle are let into the fields and they graze on the leaves and green bolls, if any, left on the plants. Later, the plant stalks are cut, at or below ground level, by the blade harrow, the *desi* plough, or hand tools, and removed to villages for use as fuel. Thus, the soil is being impoverished continually by growing cotton. It has been estimated that an average rainfed cotton crop in India takes away from the soil about 23 pounds of nitrogen, 18 pounds of phosphoric acid and 78 pounds of potash. In the case of the irrigated crop, the uptake is two or three times more. It is thus obvious that unless these valuable ingredients of plant food are returned to the soil in a useful form, the land is bound to become exhausted. The virgin land brought under the plough for the first time is far richer in plant nutrients than the land which is under continuous cropping. As each season's crop is grown and harvested, the soil suffers an annual drop in fertility, until the yield reaches a minimum level at which the annual loss and the seasonal recuperation of fertility through natural processes balance each other. This position seems to have been reached in many parts of India, so that the cotton yield per unit area is at a minimum level and fluctuates from year to year only with the character of the season, more particularly the incidence of rainfall. This is borne out by the fact that the maximum yield of cotton in India is not poorer than the maximum yields recorded in other countries. Only the average yields is much lower. With liberal manuring, proper moisture conditions in the soil, use of high yielding seed and the provision of necessary protection against insect pests and plant diseases, very high yields are being obtained by progressive cotton farmers in practically all parts of the country. It is the absence of one or more of these factors, that is largely responsible for the very low average yield.

As stated already, cotton on over nine-tenths of its annual area is grown unirrigated and is subject to the vagaries of a highly uncertain rainfall. Facilities for artificial irrigation are available for only one out of seventeen million acres under the crop. Inferior market seed is used for planting over half the annual acreage. Arrangements for plant protection also are far from adequate. Coupled with these is the fact that the vast bulk of the cotton crop is either not manured or is manured very inadequately. Generally speaking, the Indian soils are fairly rich in phosphates and potash. The addition of these plant foods to the soil is neither necessary nor productive of increased yield in the majority of cases. On the other hand, the soils are usually deficient in nitrogen as well as organic matter. The beneficial effects of the application of organic matter to the soil are well recognised by every cultivator. Whenever possible, he uses half rotten cattle-dung in his land to increase the crop

yield. Unfortunately, the application of this organic manure is neither as frequent as it should be, nor in as large quantities as are necessary to sustain the crop yields at a high level. To meet the food and other needs of a rapidly expanding population, more and more land has been brought under cultivation by destruction of forests. The indiscriminate destruction of forests in its turn has caused a progressively increasing shortage of fuel, with the result that farm yard manure which was formerly used largely to maintain the fertility of the soil and increase crop yields is now used increasingly as fuel. It is estimated that nearly 50 per cent. of the cattle-dung produced in the country at present is destroyed in this manner. Not only this but also the remaining quantity has to be apportioned between the different food and cash crops grown by the cultivator. The grain crops, fruits, vegetables and sugarcane receive a priority and cotton usually receives scant attention.

In the Punjab and the adjoining areas of Rajasthan, the available farm yard manure is applied chiefly to sugarcane, maize, fodder and garden crops. Even the food crop of wheat is largely grown unmanured. The cotton grown in rotation with the heavily manured sugarcane and maize crops, benefits from the residual effects of manure applied to the latter. The value of the cattle-dung varies with the feed of the cattle, the kind and amount of litter mixed with the excreta, and the care with which the manure is handled. Generally, no litter is used; nitrogen-rich urine is wasted and the handling of cattle-shed refuse leaves much to be desired. Ordinary bovine manure contains about 0.5 per cent. nitrogen, 0.25 per cent. phosphoric acid and 0.5 per cent. potash. To improve its fertilising value and to augment the available supplies of farm yard manure, a systematic and improved method of composting rural, town and farm refuse has been introduced during the past few years. Special campaigns have been organised annually for the complete utilisation of farm refuse, weeds, tree leaves, plant stalks, town wastes and human excreta for the purpose of composting, but the quantity of compost produced is yet relatively small and it is seldom used for the manuring of cotton. Where farm yard manure or compost is used for cotton, 5 to 10 cart loads (two to three tons) per acre are applied to the rainfed crop, and 15 to 20 cart loads to the irrigated crop. For the dry crop, the manure is carted to the field before sowing, i.e., in April or May, left in small exposed heaps for two or three weeks and then spread and ploughed in to mix well with the soil. For the irrigated cotton, the carting of the manure is started much earlier, i.e., soon after the harvest of the preceding crop of winter cereals or oilseeds, and the remainder of the process is completed quickly as the irrigated crop has to be sown before the end of April. The long drawn method of manuring the unirrigated crop is defective as not only some of the manure is blown about by wind but it also loses a portion of its fertilising value through volatilization of ammonia by exposure to sun and leaching by rains. The carting, spreading and ploughing in of the manure in this case also must be

carried out only a few days before sowing and completed in as short a time as possible, so as to reap the fullest benefit of the money and effort expended. In the past few decades, the State Department of Agriculture has encouraged the green manuring of irrigated cotton with *berseem* (Egyptian clover). However, very few cultivators have adopted the method as a regular practice. The area of green manured cotton is also very small. *Berseem* has to be planted in October, irrigated at monthly intervals, cut for fodder two or three times and the final stand buried in the soil in February or March. This irrigated winter green manure fits in satisfactorily with irrigated cotton, but the cultivators stand to lose a food crop by growing it. This no farmer usually likes to do, as the increase in yield of cotton due to green manuring is not large enough to be set-off against the sacrifices of the return from an irrigated food crop. Due to this, the progress made with the adoption of this practice has been rather slow. On the other hand, the sowing of *berseem* in the standing cotton crop just before giving the latter its final watering is fairly popular with some farmers. *Berseem* thus grown is used as cattle fodder, and after one or two cuttings the plants are allowed to set seed.

The application of chemical fertilizers was introduced a few years ago as a part of the 'Grow-More-Cotton' campaign. The fertiliser is applied partly as a basic dose and partly as top-dressing. The practice is finding favour, particularly with the growers of the better priced superior American cottons. No sacrifice of the preceding crop in the rotation is involved in this case. However, as in the case of green manuring, the cotton area actually manured with this fertilizer is very limited as yet, representing hardly 10 to 15 per cent. of the total area under this variety. The gradual reduction of the prices of ammonium sulphate in the past four years, the supply of the fertilizer on short-term credit, the quick benefits reaped by the growers by its use, and the support given for the maintenance of cotton prices at remunerative levels are likely to prove real incentives for the rapid extension of the practice in the near future. Experiments conducted in the Punjab showed that on soils of average fertility two-and-a-half to three maunds (200 to 250 pounds) of ammonium sulphate applied to an acre of American cotton increased the yield of seed cotton by four to five maunds (320 to 400 pounds) giving a net gain of Rs. 80 to Rs. 100, depending on the price of seed cotton. It was also found that the yield of manured cotton increased with: (i) increase in the quantity of water up to eight irrigations after sowing; and (ii) increase in the application of ammonium sulphate up to seven-and-a-half maunds (600 pounds) per acre. Although a normal yield could be obtained with only two-and-a-half maunds of ammonium sulphate per acre and four waterings, the most economical results were obtained with five maunds of ammonium sulphate (80 pounds of nitrogen) per acre on poor soils and two-and-a-half maunds per acre on rich soils with six irrigations after sowing. As regards the time of application, equally good results were obtained when the fertilizer was applied just before

flowering, or half at the time of thinning and half at the time of flowering. In these experiments, the fertilizer was mixed with moist earth, three to four times by weight of the fertilizer and applied broadcast. The field was then hoed to work the fertilizer well into the soil and irrigated immediately thereafter. Under rainfed conditions the application of ammonium sulphate to cotton is risky. In the absence of rain at the proper time, the fertilizer has been found actually harmful to the cotton crop. The slow acting farm yard manure has been found more useful for rainfed cotton. Besides providing plant food, it improves tilth, aeration, mechanical condition and water holding capacity of the soil.

In Uttar Pradesh and Rajasthan, a major portion of the cattle-dung produced in the dry season from October to May-June is made into dung-cakes for use as fuel. During the remaining months, it is heaped above ground or in open, uncovered pits, and used eventually as manure for maize, sugarcane and other garden crops. The cotton crop is generally grown unmanured. As in the Punjab, the green manuring of irrigated American cotton with *barseem* and the application of ammonium sulphate have been introduced in recent years in Uttar Pradesh with some success. The chemical fertilizer is used in conjunction with a basal application of farm yard manure or compost and it is usually applied at the flowering time.

In Madhya Pradesh, much of the cattle-dung is used as domestic fuel. The cotton crop is generally grown unmanured. If farm yard manure is available, it is usually applied to the preceding crop of *kharif-jowar* or to garden crops. Some farmers occasionally manure cotton also, applying about ten cart loads (three to four tons) of cattle manure per acre. Cotton being largely grown on an uncertain rainfall, the application of ammonium sulphate is not favoured. In Nimar tract, the cultivation of the leguminous crop of groundnut as a rotation crop has been taken up on a large scale. It is grown preceding cotton in the rotation, and has been found to increase the yield of cotton in a marked manner.

In Vidarbha, Khandesh and Marathwada tracts of Bombay, the cultivators manure the cotton crop once in three or four years at the rate of about ten cart loads of farm yard manure per acre. Many of them have also introduced groundnut in the rotation and grow cotton after this leguminous crop. Cotton grown on well irrigation is heavily manured like a garden crop, but even here chemical fertilizers are not generally used. The growing of a green manure crop in the monsoon season (June to September) involves the sacrifice of a food crop. Furthermore, the interval between the incorporation of the green manure in the soil in August and the sowing of the next cotton crop in the following June is too long for retaining unimpaired the fertilising value of the green manure. As such, green manuring of cotton is not practised anywhere in this region. On the other hand, the growing of a short season crop of green gram (*mung*) before the cold season crops of wheat and *jowar* is fairly

common in several parts of the tract. Green gram not only keeps down weed growth but it also leaves the land in good tilth and with a better supply of plant nutrients. In Gujerat, cotton is manured with cattle-dung fairly regularly. In recent years, manuring of irrigated cotton with ammonium sulphate in conjunction with a basal application of farm yard manure has been taken up. In Karnatak on the other hand, the manure is applied to the *jowar* crop grown in the rainy season, and cotton is, as a rule, grown unmanured. Here also, the cultivation of groundnut as a rotation crop for cotton constitutes a common practice. In Saurashtra, cotton is ordinarily grown unmanured. The growing of groundnut before cotton in the rotation is fairly common in some districts. In its Wagad tract, some farmers grow Cambodia cotton under irrigation from surface wells. This irrigated crop is always heavily manured with cattle-dung.

In Madras and Mysore, the rainfed crop is generally grown unmanured. Only the preceding cereal crop of *chulam* (sorghum) is manured with farm yard manure. In some parts of these States, cotton is grown after groundnut, thus benefiting from the fertilizing effects of the leguminous crop. Where cotton is grown intercropped with millets, the mixed crop is given an application of five to six cart loads (two tons) of farm yard manure per acre. The manure is worked into the soil by a blade harrow before sowing. The manuring of American cotton is a general practice. Five to eight cart loads of farm yard manure per acre are commonly applied as a basal dressing. Where American cotton is dibbled by hand in chess-board fashion, a handful of well rotten cattle manure is applied to each seed hole at the time of sowing. Sometimes, a mixture of ammonium sulphate and groundnut cake at the rate of 20 pounds of nitrogen per acre is applied in addition at the time of the first hoeing. In areas of heavier rainfall, the basal application of ammonium sulphate, to supply 20 pounds of nitrogen per acre to drilled cotton, has been taken up in recent years. The canal irrigated cotton in Mysore is green manured with sannhemp (*Crotalaria juncea*) or a mixture of sannhemp, cowpeas (*Vigna catieng*) and horse gram (*Dolichos biflorus*). One hundred-weight of superphosphate is usually applied to the green manure crop. The American cotton (Madras Uganda) grown under well irrigation in Madras is manured fairly heavily. Seven to twelve hundred pounds of oilcake are applied in addition to eight to ten cart loads of farm yard manure, thus supplying 60 to 90 pounds of nitrogen per acre.

Broadly speaking, the quick maturing *desi* varieties of cotton grown under rainfed conditions are only occasionally manured directly. It is the food crop grown preceding cotton in the rotation that usually receives the manure. For one thing due to large quantities of cattle-dung being used as fuel, the farm yard manure available with an average farmer is not adequate to fertilize the food crops as well as cotton. For another, food being the primary need, the food crops receive the first attention in regard to manuring.

Furthermore, in certain areas like Karnatak and southern districts of Andhra Pradesh, cotton is sown on a receding monsoon and the crop growth depends almost wholly on the moisture stored in the soil. Under such conditions, even if the crop is manured directly, the plants are incapable of making full use of it. The rotation crop of cereals grown in the rainy season is in a better position to benefit from manuring and, therefore, it is this crop which receives the manure. On the black cotton soils growing monopodial, bushy, late-maturing varieties of *desi* cotton under a more assured rainfall (as in South Gujarat), direct manuring of cotton with the slow acting organic manures is quite common. Similarly, where the higher priced American cotton is grown, even unirrigated, the crop usually receives some quantity of farm yard manure. Under other conditions, the growing of groundnut, lathyrus, etc., as a rotation crop for cotton has been adopted on a large scale to increase cotton yield. As against rainfed cotton, the irrigated crop is seldom grown unmanured. Even here, the production of the superior American cotton receives a preferential treatment due to its greater profitableness. The higher prices of American lint permits the use of more costly chemical fertilizers, which are, therefore, rapidly becoming popular in irrigated tracts. Ammonium sulphate at rates varying from 40 to 80 pounds of nitrogen per acre is commonly used as a basal dressing or half as basal and half as top-dressing. Normally, it is applied broadcast, worked well into the soil and followed immediately by an irrigation. Very often, it is used in conjunction with organic manures like cattle-dung, farm compost and oilcakes. However, the use of oilcakes as manure for cotton is on the wane due to the increasing demand for them as cattle feed and their rising prices. The green manuring of cotton in India is rare. The growing of *barseem* or other clovers in the cold weather and of sannhemp, *gavara* (cluster beans), etc., in the monsoon season as green manure crops for cotton involve the sacrifice of a food crop and is, therefore, not considered a practicable proposition. As stated already, the growing of leguminous crops in the rotation or their cultivation as mixed or intercrops is commonly practiced as a half-way house.

Numerous manurial trials with cotton have been carried out in the past on research farms in different parts of the country. The results obtained from these experiments were analysed critically a few years ago. As expected, no general conclusions on manuring applicable to the whole country were arrived at. The few broad indications that did emerge are summarised below :

1. Of the three chief elements of plant nutrition, viz., nitrogen, phosphorus and potash, the application of nitrogen alone was found essential for increasing yield. The other two, phosphorus and potash, produced no beneficial results except in isolated localities in different tracts.

2. Both irrigated and rainfed cotton responded favourably to the application of nitrogenous manures, irrigated cotton showing usually a greater reaction.
3. Under conditions of soil salinity, even irrigated cotton failed to derive much benefit from manuring. Similarly, in rainfed areas, manuring was not effective where rainfall was low, or where the soil was water-logged due to poor drainage. The correction of soil salinity and the provision of optimum moisture conditions in the soil appeared to be the true remedy in these circumstances.
4. For rainfed cotton in the black soils, groundnut cake appeared to be a more efficient source of nitrogen than ammonium sulphate. This was ascribed to the leaching effects of heavy rain on the chemical fertilizer or its inefficient utilisation under conditions of abnormal deficiency of soil moisture. The use of *neem* (margosa) cake also was fairly effective, but castor cake was generally not as good.
5. For equal amounts of nitrogen, farm yard manure as well as oilcakes usually produced a much smaller increase in yield than chemical fertilisers. This was said to be due to the slower release of fertilising elements by the bulky organic manures.
6. The application of ammonium sulphate as a top-dressing after basal manuring of the crop with farm yard or other organic manure, and the use of a mixture of groundnut cake and ammonium sulphate did not benefit rainfed cotton on the black soils to any greater degree than was expected from the individual manures on an equal nitrogen basis.
7. For irrigated American cotton in the Punjab, the best results were obtained when ammonium sulphate was applied at the time of intense flowering. In the case of early maturing *desi* cotton in Uttar Pradesh, manuring at sowing time or about six weeks later gave equally good results.
8. For the quick ripening, sympodial varieties grown on rain in Madhya Pradesh, early manuring at sowing time was found the best. As opposed to this, the manuring of late maturing, monopodial *herbaceum* cotton in Gujerat, six weeks after sowing gave a higher increase of yield than manuring at sowing time. In the case of organic manures, application before sowing was necessary due to their slower nitrification.
9. On alluvial soils the drilling of ammonium sulphate in a separate furrow alongside the row of plants was safer than drilling with the seed or applying it broadcast. The coating of seed with this fertilizer was found harmful to the germinating seed under both irrigated and rainfed conditions.

Another series of manurial trials conducted on the black soils at several different centres during the period from 1943-44 to 1947-48 gave the following main indications.

1. There is no difference in response between ammonium sulphate and groundnut cake, except under conditions of high fertility and presumably for large quantities of nitrogen, when ammonium sulphate was found to give a somewhat higher increase in yield.
2. Method of application made no difference with ammonium sulphate which may be broadcast but groundnut cake was better when drilled under conditions of high fertility and for larger applications.
3. The rate of increase in yield, per unit quantity of nitrogen, increased with increasing fertility. Manuring (with chemical fertilizer) was not found profitable on land of low fertility except under extremely favourable price conditions.
4. The application of organic manures to soils of low fertility offered a good means of improving their fertility status, and thus paving the way for subsequent profitable use of artificial manures.

It is evident that use of chemical manures without irrigation is of very limited utility. Similarly, irrigation without manuring of crops fails to produce the best results. It may also be mentioned that excessive supply of nitrogen favours rank vegetative growth and is, therefore, undesirable. About 20 pounds of nitrogen for rainfed cotton and 40 to 60 pounds for irrigated crop seem good doses under average conditions. On good soils under irrigation, the rate of application can be increased from 80 to 100 pounds of nitrogen per acre with profitable results. Organic manures like farm yard manure, compost, oilcakes, etc., should preferably be applied to rainfed crops sometimes before planting, since they must decay before their nitrogen becomes available. Nitrogen in the easily available form should not be applied much before planting, nor should it be applied too late in the season. If applied too early, a good part of it may be lost through leaching or volatilization, or utilised largely by quick growing weeds. On the other hand, if it is applied rather late in the season, it may not be used at all, or it may benefit only end-season bolls, thus delaying the arrival of ripe cotton. Application of some nitrogen before sowing and some at the beginning of the flowering season helps plant growth as well as setting of bolls, and is, therefore, likely to give the best results. The application of organic manures before sowing, and of chemical nitrogen as a top-dressing at the time of plant growth (say at first hoeing) appear advisable. In the Punjab, where the plants suffer from a heavy shedding of the early formed bolls, nitrogenous fertilizers may be applied a little later at the time of intensive flowering. For eliminating bad opening of bolls (*tirak*) in this tract, sulphate of ammonia should be applied to the crop when the leaves start showing signs of 'tannin' accumula-

tion. For the best utilisation of concentrated, quick-acting nitrogenous manures, they should not be placed beyond the reach of the developing roots, nor too close to the seeds or seedlings. The application of phosphate is seldom necessary. If phosphate-manuring is indicated in any case, superphosphate may be applied as a basal dressing preferably to a preceding leguminous crop in the rotation.

IRRIGATION, WATER CONSERVATION AND DRAINAGE

Cotton plant reacts strongly to moisture conditions in the soil. Too much as well as too little of soil water affects it equally adversely. The proper amount of soil moisture during the different stages of plant development is the most potent single factor making for a high crop yield. In low rainfall areas and in those having no facilities for irrigation, the crop often suffers from droughty conditions caused by long breaks in the rain. Under these conditions, the cotton growers adopt dry farming methods. Extensive research conducted in several parts of the country has shown that the adoption of the following practices increases crop yields appreciably.

1. Construction of contour embankments, coupled with the division of field into checks to retard rapid run-off and prevent erosion.
2. Basal application of farm yard manure at the rate of about five cart loads per acre.
3. Sowing the crop as early as possible.
4. Use of a relatively low seed rate.
5. Hoeing of the crop more frequently.

The recommended cultural methods increase soil fertility, retard rapid run-off, prevent soil erosion, encourage absorption and retention of rain water and reduce loss of moisture through evaporation. As a result of special efforts made by the State Departments of Agriculture, dry farming has found increasing favour in many parts of Bombay, the Punjab, Andhra Pradesh and Madras in recent years.

In areas, such as, the Punjab, Uttar Pradesh, Madhya Pradesh, Andhra Pradesh and Madras, where irrigation facilities are available, rain water is supplemented by artificial irrigation from surface wells, deep tube-wells, tanks, streams and canals. In some districts of Rajasthan, where the rainfall is extremely low, no cotton can be grown without artificial irrigation. In tracts of heavy soil and high rainfall, on the other hand, the crop suffers from water-logging caused by heavy or incessant rains. Provision of good surface drainage is necessary in such conditions, but a proper drainage system for cotton lands exists practically nowhere in the country. However, the cultivators drain-off excess water from their fields whenever and wherever they find it stagnating after heavy showers. There is a general awareness that even a day's submergence in standing water proves fatal to young seedlings and very harmful to grown-up plants. Similarly, in tracts where irrigated cotton

and other crops have been grown for many years and large quantities of water have been applied to the soil annually, some fields have become permanently water-logged. These lands have in many cases gone out of cultivation, as is the case in some parts of Ferozpur district in the Punjab. Attempts have been made in the past few years to reclaim such water-logged soils by providing a proper system of drainage. In some districts of Uttar Pradesh as well as the Punjab, continued heavy irrigation has produced excessive salinity in the soil or made it alkaline. In both cases, the soils have become unfit for further cultivation. Reclamation of some of these soils by leaching with water and growing a water loving crop like paddy, or by the use of chemicals, has been taken up with encouraging results.

Of the seventeen million acres planted with cotton every year, only one million acres are under the irrigated crop. The cultivation of irrigated cotton is at present largely confined to the Punjab, Uttar Pradesh, Madras, Mysore and Bikaner Division of Rajasthan. In other States too, if water for irrigation is available, the cultivators irrigate the crop occasionally whenever unduly long spells of dry weather occur in the rainy season. However, the area of such occasionally irrigated crop is insignificant. The acreage under irrigated cotton is expected to increase a great deal in the near future after the completion of large irrigation projects that are now under construction in the Punjab, Rajasthan, Uttar Pradesh, Bihar, Orissa, Madhya Pradesh, Bombay, Andhra Pradesh and Madras.

The irrigation method employed in India is what is called 'surface irrigation'. 'Sub irrigation' and 'spray irrigation' are not practised in any part of the country at present. For growing the irrigated crop, a certain amount of levelling is done before sowing, to guard against the risk of uneven irrigation. Drastic levelling is usually avoided for fear of bringing to the surface infertile sub-soil which affects the crop adversely. The 'surface irrigation' is given mostly by flooding the field. The method of 'furrow irrigation' is in vogue in only a few tracts in Madras and Mysore. In level lands, whole fields are flooded, otherwise the fields are sub-divided into small-sized checks and the crop is irrigated checkwise. An investigation conducted in the Punjab with the sizes of sub-plots (*kiaries*) varying from 1/16th acre to 1/2 acre showed that under a discharge of about one cusec in canal irrigated areas, sub-plots of 1/8th acre gave the best results. As compared with 1/2 acre plots, they caused a saving of about two-and-a-half inches of irrigation water. In flooded fields, exceptionally large quantities of water are generally used, and often-times serious damage is done to the young seedlings on the head lands. In furrow irrigation, not only comparatively less water is used but also the water is made to reach the plants by percolation, thus ensuring better aeration. As regards yield, the experiments conducted in different parts of the country have shown that there is no appreciable difference between these two methods of water.

Proper irrigation of the crop has been found to increase vegetative growth as well as the production and retention of bolls. Heavier yield is the invariable result. It has also been commonly observed that irrigation is most beneficial on fertile soils or when it is combined with heavy manuring. Furthermore, to secure the best results from varieties characterised by good lateral growth of plants, an early sowing of the crop and relatively wider spacing of plants are considered essential. The early sowing gives the plants the advantage of a long growing season. Some of the investigations conducted in the past showed that irrigation slightly enhanced the seed weight and lowered the ginning outturn but its beneficial effect on crop yield always outweighed by far these minor disadvantages. In these researches, the irrigation was further found to improve fibre maturity, but it had practically no effect, good or bad, on other fibre properties, such as fibre length, fibre weight, etc.

As stated already, the irrigated crop in northern India is sown in April or May, i.e., one or two months before the sowing of cotton grown on rains. The irrigated crop is almost always sown after a preliminary heavy watering. Sometimes the soil is irrigated twice in the two days preceding sowing to ensure deeper penetration and an adequate storage of water in the sub-soil. Subsequent waterings depend on the weather conditions, the nature of the soil, the amount of growth made by the plants and the stage of crop development. If the emergence of seedlings is poor, the crop is given a light irrigation only eight or ten days after sowing to improve seed germination. Otherwise the first irrigation after sowing is normally not given until five or six weeks later. In the western districts of Uttar Pradesh, the first post-sowing watering is often withheld up to the beginning of June and sometimes still later, i.e., for a period of eight to ten weeks. It is commonly believed that the withholding of water for this long period in the scorching hot weather retards above ground leafy growth and at the same time encourages the young plants to send roots into the deeper layers of the soils thus minimising the loss of water through transpiration and reducing the plants' dependence on artificial irrigation water. Although this belief may be well founded to a certain extent in respect of water-retentive heavy soils and of *desi* cotton, which possesses thick, small leaves and a vigorous, long tap root, it is not necessarily true of light soils or of American (*hirsutum*) cotton which generally has larger leaves and a more superficial root system. The giving of first irrigation to American cotton only three to four weeks after sowing has been found to produce beneficial results in the Punjab. However, this early watering is not heavy in view of the small size of the young plants. Another irrigation, if necessary, is given some time in June. The water starvation of young plants to the point of exhaustion is detrimental to their growth. If plants fail to recover in the afternoon from the normal mid-day wilting of leaves in the hot weather, it is a sure sign of the need for immediate watering. However, more frequent irrigations than those indicated here must also be avoided

at least until the beginning of the flowering stage. During the rainy season, the crop receives no artificial irrigation unless there is an unduly long period of rainless weather. This is particularly true of western Uttar Pradesh and the eastern and central districts of the Punjab, which normally receive 16 to 20 inches of rain in the months of July and August. In Bikaner and southern and western districts of the Punjab, where the rainfall in the corresponding period is relatively much less, the crop continues to be irrigated at successive intervals of three to four weeks. Care is always taken to ensure that the crop does not suffer from water shortage at the peak of the flowering season when many bolls have formed on the plants. This is considered the critical period of the crop. The watering of the crop at intervals of 10 to 12 days during this stage of plant development seems to be the optimum practice for most tracts. The quantity of water applied at each irrigation depends on many factors but investigations conducted at research stations have shown that three-inch waterings constitute the optimum dose for most parts of the Punjab and West Uttar Pradesh. Inadequacy of watering during the flowering season not only causes heavy shedding of young bolls but also retards boll development, thereby lowering the ultimate yield and quality of produce. With the advance of the season, particularly after the bolls start opening, the water needs of the plant decrease, and so the interval between the waterings is increased once again. The final irrigation of the season is given in September to the *desi* and the early maturing American varieties, and in October to the late maturing American types. Irrigations given after this period tend to encourage unnecessary vegetative growth and delay crop maturation, which in turn may lead to greater damage by pink and spotted bollworms or by frost. The total number of irrigations usually given to *desi* cotton in the whole season, exclusive of pre-sowing watering (*rauni*), is four to five in the canal irrigated tracts of the Punjab and Uttar Pradesh, and five to six in Bikaner. The American cotton is generally given one additional watering. The crop grown with irrigation from surface wells is irrigated usually at somewhat shorter intervals. Therefore, it is given one or two more waterings than the canal irrigated crop. Lift irrigations from wells are generally not as heavy as those from canals. With a definitely fixed rotation for availability of water in the canal irrigated tracts, the temptation to over-watering is ordinarily irresistible. With a view to determining the actual water requirements of the crop, investigations were conducted in the Punjab from 1940 to 1947. It was found that on loamy soils the best results were obtained when the cotton crop received about 34 inches of water in the whole season. This quantity included rainfall as well as the pre-sowing watering. The investigation also showed that a pre-sowing irrigation of four inches and subsequent irrigations of three inches each constituted the optimum doses. It was further found that ordinarily six post-sowing waterings were adequate, the actual number in a particular year being subject to adjustment according to the quantity

of rainfall received in the cotton growing season. Irrigations after middle of October proved to be of not much use. Liberal irrigation in the early stages of crop growth was more beneficial.

It may be pointed out that the intervals and the total number of irrigations mentioned above are only indicative. It is obvious that no hard and fast rule can be laid down in this connection. It has already been stated that the need of the crop for water varies with the variety sown, weather conditions, soil type and stage of plant growth. Under some conditions a crop may have to be irrigated at weekly or even shorter intervals, whereas in other circumstances it may not need water for even six to eight weeks. The plant itself is the best indicator for the optimum practice in every individual case.

In Madras, the irrigated cotton in the districts of Ramnathapuram and Mathurai is sown in February or March, whereas in Salem and Coimbatore, it is planted in September or October. In the latter districts, the crop benefits from 27 to 30 inches of rain from north-east monsoon, and, as such, receives less waterings (only two to three) than the hot weather (*masipatam*) cotton grown in Ramnathapuram and Mathurai. The *masipatam* crop has to face the rigours of a real hot weather during its early growth, and, therefore, needs more frequent irrigation. The interval between successive waterings varies from eight to fifteen days, depending upon the severity of the summer season and the availability of water in the wells.

In the Tanjore delta, where the cultivation of an early maturing variety of Punjab-American cotton (216F) has been introduced recently as a second crop after paddy, the crop is grown under irrigation and given five to six waterings in the whole season.

In Mysore, where the irrigated American cotton is sown either in February-March or in September-October, the earlier sowings (made in the hot weather) receive more frequent waterings than those sown later at the beginning of the north-east monsoon.

In the black cotton soil areas of Madhya Pradesh, Bombay and Andhra Pradesh, the planting of American cotton about four weeks prior to the commencement of the south-west monsoon and irrigating it two or three times to establish the plant well before the setting in of the rains, increases the yield of the crop from about 300 pounds to nearly 800 pounds of *kapas* per acre. The growing of good quality American cotton in this manner is gaining ground in these States with the extension of the irrigation facilities. Over-watering of the crop on the heavy black soils in these tracts is a major danger that should be guarded against.

HARVESTING

Flowering in cotton plants extends over a long period. All the plants in a field do not commence flowering simultaneously, nor do individual plants produce all their flowers at once. The flowering season usually starts from two

to two-and-a-half months after the sowing of seed and lasts for a period of eight to ten weeks. The crop produces only a few flowers during the first eight or ten days but after that, the rate of flowering increases rapidly. The peak rate continues for three or four weeks and then it gradually tapers off. As a result of this phenomenon, the production of ripe fruits or bolls is also gradual, being spread over a period of three to four months. Harvesting is not done, therefore, in one operation. Ripe cotton is usually collected or picked periodically, i.e., whenever a sufficiently large number of mature bolls are there to make collection an economic operation. The crop is usually harvested in three or more pickings taken at suitable intervals. The number of pickings varies with the maturation habit of the variety grown and the attendant seasonal and cultivation conditions. The varieties in which bolls mature in quick succession require a fewer number of pickings. Similarly, the varieties prone to the shedding of ripe cotton need more frequent collection of produce. In years of long continued rains and in the case of irrigated or widely spaced crops, the formation of ripe bolls lasts for a longer period. On the other hand, when rains cease early, or if the plants are spaced closely, the bolls mature in quick succession and the produce is collected in fewer pickings.

The time and duration of harvesting vary with the date of sowing, the maturation period of the variety grown, the length of the rainy season, the method of cultivation and the latitude of the locality. In the Punjab and the adjoining parts of Uttar Pradesh and Rajasthan, the produce of the rainfed crop is harvested from October to December, and that of irrigated American cotton from October to January or until the frosts kill the plants. When the rains stop relatively early, the pickings start in September and come to an end in November. In Madhya Pradesh and Vidarbha, Khandesh and Marathwada tracts of Bombay the pickings of rainfed cotton commence in the third week of October and continue till the end of December and sometimes up to January or even later. Usually harvesting is completed in four to six pickings taken at successive intervals of three weeks. The crop of partially irrigated American varieties sown in April or May produces ripe cotton in the period from September to November. In Gujerat and Saurashtra, where the crop largely consists of late sown *herbaceum* types, the harvesting starts in January and lasts up to March or April. In Andhra Pradesh, Mysore and Madras, the crop matures at different times of the year, depending on the varieties grown and the dates of sowing. The Cocanadas cotton sown in August-September is harvested in January-February, whereas the *herbaceum* crop sown in September or October is picked from January to March. Cambodia cotton planted in September-October is picked from February to May-June. The May-June flush develops from the flowers produced after summer rains. The irrigated American varieties sown in the hot months of February-March are harvested from June to September. The Mysore-American cotton planted in early rains in May, and the *mungari* (June-sown) crop in Andhra



Improved Seed Drill Operated by Bullock Power



Planet Junior Hoe being Worked Between the Ridges in Cotton Field



A Field of Surat Cotton



Picking of Cotton

Pradesh are picked from October to December as in the northern and central India. The early maturing irrigated American variety of cotton grown as a second crop after paddy in the Tanjore delta is planted in December or January as stated already. This crop is harvested from March to May. Southern India does not experience frosty weather. Therefore, subject to the adequacy of soil-moisture, the cotton crop can be grown in this part of the country practically throughout the year. The picking of ripe cotton taking place simultaneously with the sowing of seed in the same tract is a common phenomenon. The triennial Nadam cotton produces ripe bolls all the year round, but the largest number is formed in February-March, i.e., in the dry weather following good rains.

In Assam, where the rains continue much longer than elsewhere in the country, cotton is harvested from November to January-February. In the Garo Hills, the whole produce is collected in a single picking in December or January. In this case, the successive maturing bolls are left unpicked till the whole of the crop is ready for collection.

The entire cotton crop in India is picked by hand (Plate VIII). Harvesting is thus a slow and tedious operation. It is more so in the case of Asiatic varieties than in American types. The former generally have relatively small-sized bolls developing on a much large number of plants per unit area. Usually cotton is picked from each ripe boll. In some parts of Madras, if incessant rains set in at the time of picking the summer-sown American cotton, full grown green bolls are torn off from the plants and taken into the villages, where they are split open to extract the seed cotton in them even though it is somewhat immature and still wet. This immature cotton is then spread on house floors to dry. In North Gujerat and the adjoining parts of Saurashtra and Kutch, which are characterised by the prevalence of strong, hot winds during the harvesting period from February to April, closed-boll types of Wagad cotton are exclusively grown. The bolls of this variety open only partially on ripening. In these tracts, therefore, the partially open bolls as such are collected and the cotton is taken out subsequently at leisure in the farmers' homes or ginning factories by paid labour. Of the pickings taken, the middle pickings are usually the heaviest and the most important. However, the *herbaceum* variety grown in Andhra Pradesh, Mysore and Madras matures a large part of its produce in one flush, so that the first picking in this case is the principal picking. Subsequent pickings yield much smaller quantities of cotton.

Harvesting is generally done by women and children. The picking continues throughout the day, and the *kapas* (seed cotton) is collected rather carelessly. Sometimes, the boll is removed from the plant and cotton is extracted from it hurriedly, with the result that broken bits of dry bracts get mixed with it. Picked cotton is heaped by each labourer on bare earth or on dried grass along field borders. This makes the cotton dirty. At the end of

the day, the labourers carry head-loads of cotton to the farmers' houses in the villages, where it is stored in heaps under cover or in the open until it is sold to the village merchant or is carried to the market.

The wages for picking cotton are seldom paid in cash. They are usually paid in kind as an agreed portion of the day's picking. The actual daily earnings of the picking labour vary not only with this fixed ratio of payment in kind but also with the quantity of cotton picked by each person. They also fluctuate with the prices ruling from time to time for the quality of cotton which they harvest. During the peak picking season usually $\frac{1}{8}$ th to $\frac{1}{10}$ th of the day's collection is paid as wages. On the other hand, at the time of the end-season pickings, the wage ratio has to be increased to $\frac{1}{5}$ th or $\frac{1}{6}$ th to compensate for the smaller quantity of cotton available on plants for harvesting. For picking small-bolled varieties or low priced, short staple cotton, the labour has to be paid at a higher rate than for large-bolled types or more valuable long staple American cotton. Broadly speaking, the harvesting of the produce is perhaps the most costly operation in the growing of cotton. The payment of wages in kind is to some extent responsible for the generally dirty condition of the produce as the labourers always tend to increase the weight of the picked cotton to secure higher wages.

COTTON YIELDS

Though yield varies with the soil, the season, the variety grown, the efficiency of cultivation and the incidence of pests and diseases, yet, on the whole, the average yield per acre of cotton in India is low. A comparison of yield for some of the principal cotton growing countries of the world is given below.

Country	Average yield of lint (ginned cotton) in lb. per acre
U.S.A.	280
U.S.S.R.	285
China	134
Egypt	410*
Pakistan	196*
Brazil	161
India Irrigated	190
Rainfed	80

* Almost exclusively irrigated cotton.

The very low yield of the rainfed crop in India is due to the badly distributed rainfall, inadequacy of manuring, use of un-improved seed in nearly half of the area under the crop, and insufficient protection against pests and diseases. In years of well distributed rainfall and in fields properly manured and planted with improved seed, very much higher yields than 80 pounds of lint per acre have been recorded. Similarly, yields of irrigated, well manured cotton have

sometimes been as high as 400 pounds and even more of lint per acre. This only shows that under favourable conditions of season and cultivation, the crop yields in India can be as high as in other countries.

The yield per acre varies appreciably from State to State, and sometimes even in the different parts of a State. The yield of rainfed cotton in the Punjab, Uttar Pradesh and Gujerat tract of Bombay is 100 to 110 pounds of lint per acre, whereas in Madhya Pradesh, Rajasthan, the eastern parts of Bombay and Madras, it is only about 80 pounds. In Andhra Pradesh, Mysore, and Saurashtra and Kutch Divisions of Bombay, the yield seldom exceeds 60 to 70 pounds.

The yield also varies with the varieties, though they may be grown in the same tract. Generally speaking, the short staple types are more prolific. Regional difference in the yields of irrigated cotton are also equally marked. Whereas the average yield of the irrigated crop in Bikaner is only about 160 pounds, that of the irrigated crop in the Punjab varies from 180 to 200 pounds and in Madras it is about 300 pounds of lint per acre. In Uttar Pradesh, the corresponding yield is 180 to 190 pounds of lint.

The growing of improved varieties usually increases the yield by about 10 per cent. and the application of manure puts it up by 25 to 30 per cent. On the other hand, the irrigation of the crop may raise the yield two fold or more, and the growing of the disease-resistant varieties in infected soils may make all the difference between crop failure and a normal yield. The possibilities of increasing the yield per acre are thus great. The growing of improved varieties and proper manuring of the crop need all possible encouragement. Similarly, in areas of inadequate rainfall, the provision of irrigation facilities through minor irrigation schemes requires active assistance. The practice of sowing the seed in dry soil in some parts of Gujerat, Khandesh, Deccan and other tracts prior to the arrival of rains, is designed to secure an early germination of the seed and a firm establishment of the young plants in the soil before really heavy rains begin. Early sowing permits a longer period for crop growth leading to a relatively higher crop yield. However, it may be mentioned that in years of very heavy early rains, the adoption of this practice, particularly on sloping lands, runs the risk of the washing away of the sown seed. In such cases, a resowing of the fields has to be carried out

IMPROVED VARIETIES

Botanically, the cotton varieties of India, belong to three distinct species, namely, *Gossypium arboreum*, *Gossypium herbaceum* and *Gossypium hirsutum*. Of these, *G. arboreum* is supposed to be indigenous to India. Fragments of yarn found in the excavation at *Mohen-jo-daro* (Sind, Pakistan) have been identified to belong to this particular species. The second species *G. herbaceum* seems to have been introduced in India from the Middle-East countries, and

the history of its introduction can be traced back to the early days of the British East India Company.

The *arborescens* group includes varieties which are predominantly coarse and short stapled, though a few among them are medium stapled and fairly fine. They are cultivated to a varying extent in almost all cotton growing States.

The varieties belonging to the *herbaceum* group are generally much finer and longer in staple than the *arborescens* varieties. Their cultivation is confined to parts of Bombay, Madras, Andhra Pradesh and Mysore.

The *hirsutum* group includes varieties which are medium to long staple, and are much finer than those of the other two groups. These varieties are largely grown in the Punjab, western Uttar Pradesh, Bikaner Division of Rajasthan and parts of Andhra Pradesh, Madras and Bombay. The cultivation of these varieties is also spreading in some parts of Mysore and Madhya Pradesh.

For purposes of trade, the cotton varieties of India have been classified into 13 groups in accordance with their staple length and region of cultivation. The commonly known trade varieties, according to this classification, and their tracts of growth are given below.

Trade varieties	Tracts of growth
Bengals	Punjab, Uttar Pradesh, and Rajasthan.
Americans	Punjab, Uttar Pradesh, Rajasthan, Mysore, Madhya Pradesh, Bombay and Andhra Pradesh.
Oomras	Madhya Pradesh, Vidarbha, Marathwada and Khandesh tracts of Bombay.
Gaorani	Marathwada tract of Bombay.
Central India	Madhya Pradesh.
Surti	Surat, Baroda and Broach districts of Bombay.
Dholleras	North Gujerat, Saurashtra and Kutch tracts of Bombay.
Southerns	Mysore State, and Kurnool and Guntur districts of Andhra Pradesh.
Tinnevellis	Madurai, Ramnathapuram and Tirunelveli districts of Madras.
Cambodias	Coimbatore, Salem, Tiruchirapalli, Madurai, Ramnathapuram and Tirunelveli districts of Madras.

Trade varieties	Tracts of growth
Madras Uganda	Madurai, Ramnathapuram, Tirunelveli, Chingleput and South Arcot districts of Madras, and Chittor and Nellore districts of Andhra Pradesh.
Salems	Salem, Coimbatore and Tiruchirapalli districts of Madras.
Comillas	Hill tracts of Assam.

With a view to evolving high yielding and better quality types, the cultivation of which is more remunerative to the grower, a vast amount of crop improvement work has been done in this country during the last 30 years under the auspices of the Indian Central Cotton Committee. Already, a number of improved types of *arboreum*, *herbaceum* and American varieties, to suit different climatic conditions and tracts, have been evolved. The important improved types which are being recommended for cultivation in different States are as follows:

Variety	Staple length (inches)	Ginning percentage	Sowing time	Talukas, districts or tracts for which recommended
Kalyan	26/32 to 27/32	40 to 43	July-Aug.	Wagad tract of North Gujerat consisting of Ahmedabad and Mehsana districts of Bombay.
Vijay	24/32 to 28/32	37 to 40	July-Aug.	Broach tract of middle Gujerat constituted by Kaira, Sabarkantha, Panch Mahals, parts of Broach (north of the river Narbada) and Ahmedabad district of Bombay. Also suitable for part of Baroda district lying between Narbada and Mahi Rivers.
Suyog	28/32	36.5	July-Aug.	Surat tract of South Gujerat (south of the river Narbada)

Variety	Staple length (inches)	Ginning percentage	Sowing time	Talukas, districts or tracts for which recommended
2087	29/32	36·5	July-Aug.	Nawapur <i>taluka</i> of West Khandesh tract.
Virnar	28/32	38 to 41	June-July	Khandesh tract and Buldana district of Bombay.
Jarila	28/32	35 to 36	June-July	Khandesh tract and Buldana district of Bombay.
Jayadhar	28/32 to 29/32	33 to 34	Aug.-Sept.	Kumpta-Dharwar tract and Raichur and North Chitaldrug districts of Mysore.
Laxmi	29/32 to 30/32	34 to 35	Aug.-Sept.	Dharwar, Shimoga and Raichur districts of Mysore.
Pratap	29/32	32 to 33	June-July	Saurashtra Division (Gohilwad and Madhya Saurashtra districts) of Bombay.
Co.2	30/32	34 to 35	Aug.-Sept.	Coimbatore, Salem, Tiruchirapalli, Ramnathapuram, Madurai and Tirunelveli districts of Madras.
Madras Uganda	1 to 1-1/16	34 to 35	Aug.-Sept. and Dec.-Mar.	Madurai, Ramnathapuram, Tirunelveli, South Arcot and Chingleput districts of Madras, Chittoor and Nellore districts of Andhra Pradesh, Baroda district of Bombay and Chitaldrug district of Mysore.
K.2	28/32 to 29/32	29 to 30	Aug.-Sept.	Madurai, Ramnathapuram and Tirunelveli districts of Madras.

Variety	Staple length (inches)	Ginning percentage	Sowing time	Talukas, districts or tracts for which recommended
K.5	28/32 to 29/32	29 to 30	Aug.-Sept.	Coimbatore, Tiruchirappalli, Madurai (area north of Vaigai) and Salem districts of Madras.
N.14	28/32 to 30/32	24	Aug.-Sept.	Kurnool district of Andhra Pradesh (excepting Pattikonda taluka).
Westerns 1	24/32 to 26/32	30	Aug.-Sept.	Bellary district of Mysore and Anantapur, Cuddapah and Kurnool districts of Andhra Pradesh.
C.1	22/32 to 26/32	28	June-July	Guntur and the adjoining districts of Andhra Pradesh.
C.2	22/32 to 26/32	30	June-July	Guntur and the adjoining districts of Andhra Pradesh.
881F	22/32	36	June-July	Parts of Kurnool, Anantapur and Cuddapah districts of Andhra Pradesh and Bellary district of Mysore.
216F	28/32 to 30/32	32 to 33	April-May	Districts of Hissar, Rohtak, Karnal, Gurgaon and Patiala of the Punjab, Etah and Aligarh districts of Uttar Pradesh, Canal tracts of Bikaner (Rajasthan) and the Tanjore delta area in Madras.

Variety	Staple length (inches)	Ginning percentage	Sowing time	Talukas, districts or tracts for which recommended
320F	29/32	33 to 34	April-May	Districts of Ferozepore, Amritsar, Jullundur, Ludhiana, Patiala and Batala <i>tehsil</i> of Gurdaspur in the Punjab.
231R	22/32	42 to 43	April-May	Sub-montane tract of the Punjab consisting of Gurdaspur (excepting Batala <i>tehsil</i>), Hoshiarpur and Ambala districts.
H.420	28/32	32 to 33	June-July	All cotton growing districts (other than Buldana) of Vidarbha Division of Bombay.
Buri 0394	28/32 to 29/32	33 to 34	June-July	All cotton growing districts (other than Buldana) of Vidarbha Division of Bombay.
Parbhani- American	28/32	30 to 31	June-July	Parts of Adilabad district of Andhra Pradesh and Aurangabad district of Bombay.
Gaorani 6	28/32 to 30/32	31 to 32	June-July	Marathwada Division of Bombay, Adilabad district of Andhra Pradesh and Bidar district of Mysore.
Gaorani 12	28/32 to 30/32	31 to 32	June-July	Parbhani and Aurangabad districts of Bombay.
35/1	26/32	34 to 35	May-June	Western and central districts of Uttar Pradesh.

Variety	Staple length (inches)	Ginning percentage	Sowing time	Talukas, districts or tracts for which recommended
M.A.5	1-1/16	34 to 35	June-July	Hassan, Mysore, Shimoga and Chikmagalur districts of Mysore State.
Malvi 9	22/32 to 24/32	34 to 35	June-July	Malva Plateau of Madhya Pradesh.
Indore 2	24/32 to 26/32	31 to 32	June-July	Malva Plateau of Madhya Pradesh.
Indore 1	24/32 to 26/32	30	June-July	Merwar Division of Rajasthan.
C.520	24/32	35 to 36	June-July	Jaipur Division of Rajasthan.

The Indian Central Cotton Committee in collaboration with the State Governments, is financing a number of seed multiplication and distribution schemes in various parts of the country to help make available to cotton growers pure seeds of these improved varieties. The distribution of pure seed of these types is also being vigorously carried out under the special Cotton Extension Scheme of the Government of India since 1950-51. Though a substantial progress in extending their cultivation has already been made, the area covered so far by the improved types forms only 50 per cent. of the total area of the cotton crop in the country. There is thus considerable room for further expansion of the growing of the improved varieties.

In order to maintain the purity and quality of the improved varieties grown on a large scale, many of the States have enacted Cotton Control and Transport Acts which regulate the transport of cotton and cotton seed to be the specially constituted 'protected' areas. A few States have gone to the extent of taking powers by law to prescribe the compulsory cultivation in notified tracts of only such varieties as are approved by their Agriculture Departments. The growing of other varieties is prohibited in such areas.

SEED MULTIPLICATION

For the multiplication of improved seed, special steps are required to be taken. The process begins with the production of nucleus seed by the deliberate self pollination of flowers by the cotton breeder at his research station.

The first generation seed obtained from this selfed seed plot is multiplied in the following year under favourable conditions of cultivation at the research station itself, as far as possible. A low seed rate is used to cover the largest

possible area with this valuable seed. The seed is dibbled in properly spaced seed holes on well manured soils and the crop is irrigated, if irrigation facilities are available. This method is adopted in order to secure maximum yield from a given area.

During the growing season, and more particularly at flowering time, the crop is examined in the field for its purity. All plants not true to type are uprooted to avoid further contamination and deterioration. The seed thus produced is called the 'foundation stock', and it is used for further multiplication either on the Government Seed Farms, or on private farms of registered cotton growers who undertake to grow the crop according to the instructions issued by the Agriculture Department, permit its inspection for purity, allow removal of plants not true to type, gin the produce under the supervision of Agricultural Officers, and sell the seed back to the Agriculture Department at an agreed price.

It is advisable to organise the multiplication of this foundation seed in compact blocks in one or two villages to ensure good cultivation and facilitate expert supervision required for obtaining the highest possible yield and to maintain its purity. If the quantity of seed available permits, the provisions of the Pure Seed Act may be applied to the villages selected for seed multiplication.

The growing of the improved variety to the exclusion of those not approved by the Agriculture Department can be made compulsory under the Pure Seed Act. However, before the application of this Act is resorted to, it is necessary to make sure that adequate quantities of pure seed of the improved variety are available to cover the entire cotton area of the selected villages.

The seed produced by the selected villages or the registered growers is purchased and stocked by the Agriculture Departments for distribution to the farmers of other villages in the following season for further multiplication. Arrangements somewhat similar to those described above are made for crop inspection, supervision over ginning and sale of seed either to the Agriculture Department itself or its approved agents, such as co-operative societies or reliable village merchants. This process is repeated for another year or two until enough pure seed of the improved variety becomes available for covering the entire cotton area of a given tract for which the variety is recommended for cultivation.

In almost all parts of India, the multiplication and large scale supply of pure seed of improved varieties has so far been the function of the Agriculture Department. Although in some States Co-operative Societies have started taking a hand in the ginning of produce, purchasing the seed and its distribution in the two or three final stages, yet they play practically no part in the multiplication of foundation seed or the stages immediately following it.

A stage has now been reached when in order to cover still larger areas with pure seed of improved varieties it is necessary to secure the participation

of well organised co-operative societies in even the early stages of seed multiplication. The exact arrangements required to be made in this connection will vary to some extent with the local conditions. The Agriculture and the Co-operative Departments concerned are the best authorities to advise in the matter. The decentralisation of the arrangements for the multiplication of pure seeds will not only permit a much larger expansion of area under improved varieties, but will also cheapen the cost of the seed.

It has been mentioned above that the growing of improved types of cotton usually increases the yield of *kapas* by about 10 per cent. The noteworthy feature is that this extra yield is obtained by the cotton grower at practically no extra expenditure. The cultivation of improved types of cotton is, therefore, encouraged to the maximum extent possible in all parts of the country. Taken together with timely sowing, proper cultivation, suitable manuring, irrigation if possible, effective protection of the crop against insect pests and diseases, clean picking and proper processing of the produce in the ginning and pressing factories, the cotton growers will earn much higher income than they will do otherwise.

CHAPTER III

DISEASES

The cotton crop in India is known to suffer from a number of diseases, among which the Root Rot and the Wilt are particularly widespread and cause heavy losses. The Bacterial Blight and the Anthracnose, too, in certain areas assume serious proportions when environmental conditions are congenial for their development. Other diseases, though individually not so important from the economic point of view, may still collectively bring about a heavy reduction in yield, and as such, their occurrence is also a matter for serious concern. Moreover, the new varieties which are being evolved in various parts of the country may bring into prominence diseases which at present are considered to be of minor importance and are generally overlooked. This chapter deals with fourteen fungus diseases, one each of bacterial, nematode and virus origin, and two physiological disorders which are met with in the cotton crop in India. Several other fungi, e.g., *Chaetomium amphitrichum* Corda, *Leveillula taurica* (Lev.) Arn., *Oidium* sp., *Colletotrichum* sp., *Pestalotia gossypii* Hori ex S. Thuruda, *Diplodia gossypina* Cke. and *Verticillium dahliae* Klebahn, have also been reported, but these have been studied purely from the taxonomic point of view, and have not been, therefore, taken into account. A severe non-parasitic malformation of leaves of cotton characterised by inward rolling of their margins has also been reported from the Punjab (Vasudeva, 1940) and is considered different from the one reported earlier by Afzal *et al.* (1935).

No systematic assessment of losses due to cotton diseases has been carried out in any country except in the United States where an overall loss of 10·4 per cent. of the cotton lint has been recorded during the last four years. On the other hand, the losses caused by individual diseases as estimated by some experienced plant pathologists in different countries have been reported to be considerably higher. In India, no systematic effort has been made to assess loss of the magnitude, but even on a conservative estimate it would not be less than 10 per cent. of the total production, or about Rs. 18 crores annually taking the price of seed cotton at Rs. 26 per maund. Techniques for the assessment of losses from certain diseases like *Verticillium* Wilt, Root Knot, Bacterial Blight, etc., have been developed, but some of these are open to criticism. It is essential, therefore, that work in this direction is intensified.

The storage of cotton seed is another problem of importance. When large quantities are stored, the seed is likely to get heated and deteriorate in quality resulting in greater susceptibility to the attack of micro-organisms. Moreover, under warm and humid conditions of storage, cotton fibres are liable to be attacked by fungi and bacteria. Little work in this direction

appears to have been done in India so far.

FUNGUS DISEASES

WILT

It is believed that the disease originated somewhere in Mexico or Central America and that it eventually spread to other cotton growing areas through infected seed. It is widely prevalent throughout the sandy acid soils of the United States. In Africa, it is serious in the rich soils of lower Egypt. It also occurs in Belgian Congo and Central and French Equatorial Africa. Recently, attempts have been made to grow cotton in Languedoc, and this has led to the introduction of the disease in that region (Bernaux, 1952). In Europe, Guillemat (1952) has reported cotton wilt from southern France. It is presumed that the disease was introduced there as a result of sowing infected seed imported from the United States. Sutic (1954) has reported that *Fusarium vasinfectum*, the cause of cotton wilt, has been responsible for widespread decay of the crop in the regions of Strumia, Devdelija, Macedonia and Yugoslavia. In the U.S.S.R., the disease occurs in Azerbaijan, Russian Turkistan and Tashkent. Francis (1952) has recorded that the disease is widely distributed in the West Indies, though the total amount of infection is small.

The first record of this disease in India is by Evans (1908) who found it to have caused much damage to the crop at the Nagpur Experimental Farm. The disease is now widespread in the central and western regions of India. It is prevalent in black soils of Madhya Pradesh, Khandesh, Karnatak and South Gujerat, but is not common in regions predominant with alluvial soils such as North Gujerat, Kathiawar, Uttar Pradesh and the Punjab. It has been reported from Hyderabad as also from black soils of Malva (Kulkarni, 1941). The regional distribution of cotton wilt in India seems to be limited by soil temperature and soil type. The disease is found in areas where soil temperature during the growing period of cotton ranges from 20° to 30°C. The absence or low incidence of the disease in the Indo-Gangetic plain is due to high soil temperatures prevailing during the summer months (Kulkarni, 1934). In Broach district of Bombay State, wilt causes much damage in black soils, but is completely absent in the sandy alluvial (*goradu*) soils. It is presumed that the wilt pathogen is rapidly destroyed in alluvial soils during the hot months preceding the monsoons.

The losses in yield caused by the disease are due to reduced stands, stunted plants, small bolls and poor quality of the lint. There is not much difficulty in assessing over all losses in case of cotton wilt as the pathogen kills groups of plants and leaves bare patches of variable size in the field. When the disease is sporadic and the plants die singly in the field, the amount of loss to the crop depends on the age at which the plants die and also on the habit of the variety. Butler (1933), from the study of this sporadic type of wilt in some parts of Khandesh in India, concluded that there was little loss when the plants wilted

before they were half grown unless the incidence of the disease exceeded 10 per cent. The Khandesh cotton branches freely so that the gaps caused by the death of young plants are largely filled by the surrounding ones. This is not possible in the case of a cotton of Sakel habit which does not form extensive lateral branches to fill up the spaces.

The exact losses due to the disease in different cotton growing countries of the world except in the U.S.A. have not been determined. In the United States, before the development of wilt-resistant varieties, individual farmer would often lose 75 to 90 per cent. of the crop, but now with the introduction of resistant varieties losses from wilt and nematodes together probably do not exceed 3 to 4 per cent. in any State (Smith, 1953). In India, before the introduction of wilt-resistant varieties, 40 to 60 per cent. loss had been commonly observed by Kulkarni and Mundkur (1928) in some fields of Khandesh and Karnatak. In Madhya Pradesh, a loss of 5 to 47 per cent. has been recorded in certain areas on the basis of careful local observations (Ajrekar and Bal, 1921). The disease is more serious in Bombay State, particularly in Karnatak, than in any other part of the country. Kulkarni (1934) has reported a loss of 5 per cent. for Bombay State alone.

In the United States, the wilt fungus is known to attack and produce wilt symptoms on cotton, okra, coffee weed and some varieties of burley tobacco. It has also been reported to enter the roots of a number of other different hosts but without producing any wilt symptoms (Smith, 1953).

The pathogen is also known to attack pigeon pea and sannhemp (Butler, 1918; Uppal and Kulkarni, 1937), but the strains of the fungus on these crops are highly specific and do not infect cotton (Padwick, 1940). Padwick, Mitra and Mehta (1940) do not consider the wilt fungi attacking pigeon pea and sannhemp as strains of *Fusarium oxysporum* f. *vasinfectum* (*Fusarium vasinfectum*) but regard them as varieties of *Fusarium udum* Butler.

Symptoms. The disease affects the host at all the stages of its growth. The earliest symptom to appear on the seedlings is the yellowing and browning of the cotyledons. The base of the petiole at this stage shows a brown central ring, followed by the death and falling off of the affected parts.

In young and adult plants, the leaves lose their turgidity, first turn yellow and then brown, start wilting and finally drop off. Discolouration of the leaves starts from the margins and spreads towards the mid-ribs. An abscission layer is formed at the base of the petiole and the leaf falls off. The older leaves towards the base are affected first, followed by younger ones towards the top. Wilting may be complete or partial (Plate IXa); in the latter case only one side of the plant is affected while the other remains free. In completely wilted plants, cotton stalks with bare branches are left in the field. The tap root of a wilted plant is usually stunted and the laterals are less abundant. The plants affected by the wilt early in the season remain considerably stunted as compared to the healthy ones. The main shoot of such plants

remains short though one or more lower branches may grow normally. Wilted plants may sometimes recover by the development of new stunted shoots at the base.

The most outstanding and diagnostic symptom of the disease is the browning and blackening of the vascular tissues. The transverse section of the affected branch reveals a discoloured ring in the woody tissues of the plant. In severe cases of wilt, discolouration may extend throughout the plant, starting from the roots and extending to the stem, leaves and even bolls. Discolouration of the woody tissues can be traced up on the surface of the host as black streaks. In wilted seedlings it is seen on the surface at the base of the stem and on the tap roots. In adult plants, however, such discolouration can be seen only on removing the barks, when black tissues are seen below in streaks or stripes.

The disease usually occurs first in small scattered patches in the field but with the increase of inoculum, these patches increase in size from year to year. As a rule wilting is gradual, but sometimes the plants may wilt suddenly. The wilted plants may produce some bolls, which are usually small and open prematurely. The plants affected by the disease may die at any stage of their growth, the mortality being maximum during the period when the crop finishes its vegetative phase.

Etiology. Evans (1908), who first drew attention to this disease in India found it to be caused by *Neocosmospora vasinfecta* Smith which was considered in those days to be the perfect stage of *Fusarium vasinfectum* Atk., the cause of cotton wilt in America (Smith, 1898). Butler (1910) disproved the parasitism of *Neocosmospora vasinfecta* on cotton and also showed that it was not the perfect stage of *Fusarium vasinfectum*. The fungus is a common soil saprophyte which develops its perfect form on the roots of wilted cotton and many other plants. In 1914, he showed that the disease was caused by a *Fusarium* sp. which was quite different from *Fusarium vasinfectum* Atk. In 1926, however, he reversed this opinion and considered the causal fungus to be a strain of *Fusarium vasinfectum*. In the inoculation experiments carried out by him some of the plants escaped infection, while others died even though all were exposed to the same intensity of infection. This led him to conclude that the irregular results of inoculation might be due to some factor other than the soil as the same kind of soil was used in all the experiments. Ajrekar and Bal (1921), working on the wilt disease of cotton in Madhya Pradesh, confirmed the finding of Butler that the disease is caused by *Fusarium* sp. This claim, however, was refuted by Dastur (1924, 1929) who felt that wilt disease of cotton is in reality a physiologic disease caused by the accumulation of iron and aluminium salts in the tissues of the plants. He put forward the argument that in the experiments carried out by Ajrekar and Bal, the incidence of the disease was low and irregular and that no satisfactory explanation had been given by them as to why some plants escaped the disease while others died in the same pot.

He himself got inconsistent results from the inoculation experiments and, therefore, concluded that *Fusarium* was not the cause of the disease.

Ajekar (1928) and Bal (1928) have, however, contradicted Dastur's theory of accumulation of iron and aluminium salts in the plant tissues as the cause of cotton wilt in India. According to them the greater accumulation of aluminium salts as noticed by Dastur in wilted plants than in the non-wilted ones, is by no means a conclusive evidence that the fungus is not the cause of the disease. "It is quite conceivable", states Bal (1928), "that fungoid attack might so change the physiological processes in the plant that the normal process of absorption of minerals by roots is interfered with, allowing an excess of aluminium to be taken up by the plant."

Kulkarni's (Kulkarni and Mundkar, 1928; Kulkarni, 1934) inoculation experiments have confirmed the parasitism of *Fusarium vasinfectum* on cotton. He has shown that, for securing a high percentage of deaths in the inoculation experiments, it is essential that the fungus should be present throughout the soil where the host roots are likely to react and not merely in its superficial layer. Furthermore, the soil should be inoculated before the seed is sown and not during the growth of the plants. He has also shown that the disease is severe at 20° to 27°C. It is possible that the earlier workers failed to get uniformly successful infection because of the imperfect knowledge of conditions under which the infection takes place.

Snyder and Hansen (1940) in revising the species concept of the genus *Fusarium* have regarded the various vascular wilt producing *Fusaria* as biologic forms of *F. oxysporum*. The one which causes cotton wilt has been named as *Fusarium oxysporum* f. *vasinfectum* (Atk.) Snyder and Hansen.

The fungus may enter the host through healthy roots (Dharmarajulu, 1932). Laboratory experiments carried out in the United States indicate that, with large amount of inoculum, the fungus enters healthy cotton roots in the absence of openings made by the nematodes. Field experiments, however, show that in nature the wilt fungus mostly enters through the openings made by the earthworms (Smith, 1953). Young and Smith (1953) have obtained successful control of the disease in the United States by fumigating the soil before sowing with Dieldrum W. 85 (Ethylene dibromide) which reduces or totally eliminates the nematodes in the soil. No attention has ever been paid to the association, if any, of the nematodes with cotton wilt in India. Study of this problem from this angle appears to be necessary.

After entering the small roots, the fungus moves up through the xylem vessels by the growth of the mycelium and movement of spores. The mycelium partially or completely plugs the xylem vessels and thereby stops or lowers the upward flow of water along with the dissolved salts. This results in wilting and withering of the plant. If bolls are present, the mycelium may grow through the peduncle into the seed. The water conducting channels become

first yellow, then brown and later black by the formation of gum-like substances and growth of tyloses.

The active factor responsible for wilting of the plant seems to be some toxic compound. The nature of this principle is not known. It is resistant to boiling and autoclaving at 110° to 115°C. and is filterable through the porcelain filters (Kalyanasundaram and Lakshminarayanan, 1953; Kulkarni and Mundkur, 1928).

The fungus shows luxuriant growth on media containing glucose, fructose, sucrose or inulin as the source of carbon. For consuming nitrogen it prefers to assimilate nitrates rather than ammonium salts. It can tolerate a wide range of temperature, from 11° to 35° C. Its thermal death point is beyond 50°C. and the optimum pH-range for its growth lies between 5.2 and 7.2 (Kulkarni, 1934; McRae, 1926; Mitra and Kheswalla, 1935). Aeration, though promotes its mycelial growth, progressively inhibits its sporulation (Sarojini and Yogeswari, 1947). Sulochana (1952a) has shown that percentage germination of conidia of *Fusarium oxysporum* f. *vasinfectum* is low in soil samples amended with the micro-elements such as zinc, molybdenum, lithium, aluminium, nickel, boron and cobalt than in the untreated control soil. It has been shown that the fungus is more tolerant to adverse physical conditions in the soils than those favouring general microbial activity. The fungus remains persistently undiminished under sterile conditions for more than 24 months, but in unsterilized soil it is decomposed due to microbial antagonism (Subramanian, 1950).

Predisposing Factors. Soil temperature and soil moisture greatly influence the incidence of the disease. Uppal and Kulkarni (Uppal, 1948) have shown that in controlled experiments the disease is serious between 22° to 30°C., decreases at 32°C. and is completely inhibited at 35°C. and above. Between 24° to 28°C. the plants are attacked very severely in the early stages of their growth. In green house studies in the United States, maximum wilt development has been obtained at 80 to 90 per cent. of the water holding capacity of the soil. High levels of soil moisture, however, tend to lower soil temperature and thereby reduce the incidence of the disease under natural field conditions. Hot and dry periods of rather long durations followed by rains provide conditions favourable for maximum wilt development (Smith, 1953).

Soil texture and soil reaction, besides other factors, seem to have a great influence in rendering the plants susceptible or resistant to the disease. Wilt is found in India on black cotton soils which are heavy clays with an alkaline reaction, and is unknown in light loamy alkaline soils. In the United States, on the other hand, it is found on light sandy acidic soils. In India, all the American cottons are immune to the Indian strain of *Fusarium oxysporum* f. *vasinfectum*. Even the American strain of the fungus, when brought to India, could not infect the American cottons grown on the Indian soils, though these

cottons are highly susceptible to the same fungus on the American soils. Similarly, when the susceptible Indian varieties were tested on the sandy acid soils in the United States, they were found to be immune to the American strain of the fungus and comparatively less susceptible to the Indian strain (Mundkur, 1936).

Potash tends to reduce wilt, while nitrogen and phosphorus increase it within certain limits (Ambegaokar and Wad, 1936; Smith, 1953). Sulochana (1952 a, b) has shown that incidence of cotton wilt is reduced in zinc amended soils and is increased by treatment with manganese. Farm yard manure seems to have some controlling effect on the disease in the later stages of the crop (Kulkarni, 1934).

Subramanian (1946) has shown that in sterilized soils the fungus shows healthy growth with the production of numerous conidia and chlamydospores. In the unsterilised soils, on the other hand, the pathogen is attacked and decomposed by the antagonistic soil microflora, especially the bacteria.

Perpetuation of Disease. The wilt fungus survives in the soil on organic matter, where it produces conidia and chlamydospores. The conidia are relatively short-lived, while chlamydospores are long-lived and act as resting spores. On germination, under favourable conditions, both these types of spores give rise to mycelium, which infects the roots of the host plant. Kulkarni (1934) has reported that the fungus is found fairly deep (up to 20") in the soil. Since the soil temperature below six inches does not rise above an average of 32°C., the organism, once introduced, can remain there in viable form for a number of years. In the United States, it has been known to survive even for 25 years in a field which was not sown with cotton during this period.

Although cotton wilt has been shown to be internally seed-borne, only a small percentage of the seed harbours the dormant mycelium. Infected seed, however, does not constitute an important source of primary infection, though it may play a great role in the introduction of the disease to wilt-free areas.

Spread of Disease. Once the disease is introduced in a wilt-free area through the infected seed, it spreads there from field to field or from one part of the field to another by means of spores and mycelial bits which are disseminated by irrigation or rain water and several other agencies. Spores that are produced on the above-ground parts of the host may be blown about by wind and thus spread the disease.

Control Measures. The principal control measures are described below.

Seed Treatment : Disinfection of the infected seed by hot water is not possible because the temperature (58°C.) which kills the mycelium inside the seed also causes injury to the embryo. Possibility of disinfection of seed by che-

motherapeutic means, however, remains to be explored.

Cultural Methods : Except soil temperature, other factors like moisture content, reaction and physical texture of the soil have little to offer from the stand point of view of control. Prevalence of the favourable soil temperature for the development of the disease during June and July shows the inadvisability of earlier sowing of cotton. Control of the disease by ploughing the infected fields to expose the soil to high temperatures is almost impracticable as the fungus occurs as deep as 20 inches in the soil and the soil temperature below six inches does not normally go above 32°C. Mixed cropping of susceptible cotton with immune varieties offers some protection to the crop against wilt particularly during the early stages. The immune crop provides shade which lowers the soil temperature. As the unfavourable low temperatures restrict the spread of the pathogen, the incidence of the disease is reduced (Aiyer, 1949).

In view of the fact that the fungus can persist in the soils for a number of years, crop rotation is not of much use for the control of the disease.

As already stated, potash reduces wilt while nitrogen and phosphorus increase it within certain limits. By combining appropriate amounts of nitrogen, phosphorus and potash it has been possible to prevent losses from wilt and at the same time have a vigorous growth of the cotton plants (Smith, 1953). Kulkarni (1934) has shown that farm yard manure at the rate of 40 tons per acre can control the disease in the later stages of the crop.

Biological Control : Pot experiments carried out by Kublanovskaya (1952) at Tashkent in the U.S.S.R. have shown that the wilt can be reduced by 30 to 32 per cent. in unsterilized soil and by 44 to 53 per cent. in sterilized soil by inoculating the soil with actinomycetes.

Resistant Varieties : In India, the disease has been reported to affect only cotton. All the varieties of *Gossypium arboreum* and *Gossypium herbaceum*, the two indigenous species, are susceptible. The varieties of *G. hirsutum* and *G. barbadense*, introduced from America and Egypt, respectively, are immune to the Indian strain of *Fusarium oxysporum* f. *vasinfectum*, though they are highly susceptible to the disease in the countries from where they have been imported and the same had happened when the susceptible Indian varieties were grown in those countries (Mundkur, 1936; Fahmy, 1928). In the absence of any good direct method of control, development of wilt-resistant varieties is undoubtedly the best method of control in this case. The selections made under optimum condition of infection (soil temperature being 24° to 28°C.) have resulted in the production of 100 per cent. wilt-resistant types which do not breakdown unlike the field selected resistant strains which lose their resistance due to the variations in soil temperatures in different years (Uppal, Kulkarni and Randive, 1941). Selections, possessing high degree of wilt resistance and desirable agronomic characters, have been obtained from *G. herbaceum* var. *frutescens*, *G. arboreum* var. *neglectum* f. *bengalensis* and *G. arboreum* var.

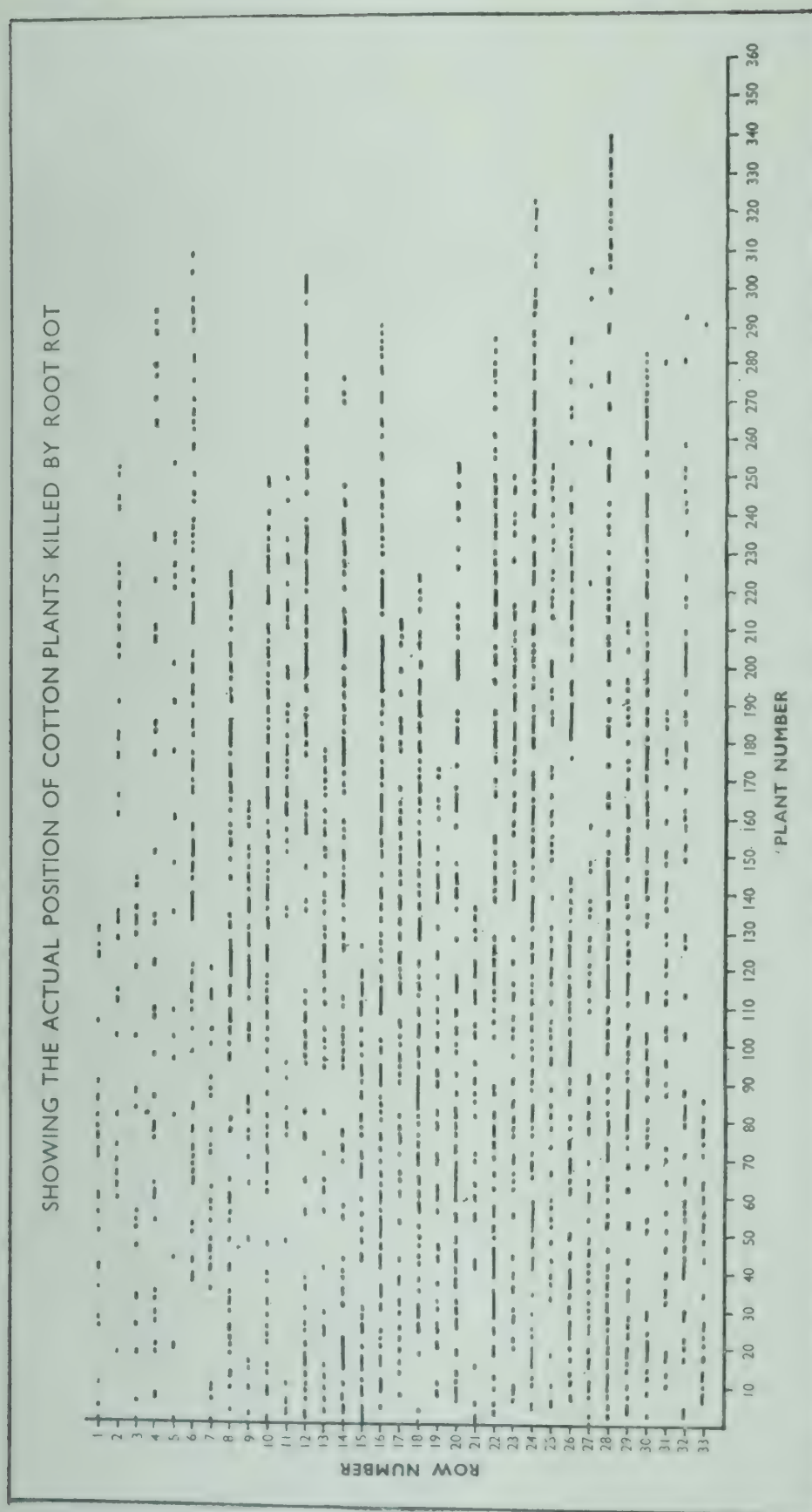


Fig. 31. Diagrammatic Field Showing Spread of Root Rot Disease

neglectum f. *indica* (*G. indicum*) by the State Department of Agriculture, Bombay. Jayadhar, Jarila, B.D.8, Vijay, Pratap and Verum are some of the wilt-resistant varieties which are widely cultivated in those cotton growing areas of India where the disease is a serious problem.

Recently in the United States, it has been found that a very high degree of resistance to *Fusarium* wilt is determined by two dominant pairs of factors in the Sea Island cotton. This has much simplified the work of selection for resistance in the cotton breeding programme. The wild or 13-chromosome cottons of Asia and America have also been found to possess a high degree of resistance and these cottons are now being used in crosses for improving the susceptible commercial varieties (Smith, 1953).

ROOT ROT

The root rot caused by *Rhizoctonia bataticola* (Taub.) Butler and *R. solani* Kühn is one of the most serious diseases of cotton in India and has been reported for almost all the cotton growing tracts of the country. The disease occurs in a severe form chiefly in the irrigated areas of the Punjab and on the rainfed sandy alluvial soils of Gujerat. It is of minor importance in Madhya Pradesh. The regional distribution of the disease in India seems to be limited by soil temperature. High soil temperatures favour the development of the disease and for this reason it occurs in a severe form in the Punjab and Gujerat. It has also sometimes been reported from black soil areas of Khandesh, Hyderabad-Deccan and parts of Bombay-Karnatak where high soil temperatures prevail early in the growing season.

Root rot of cotton is by no means restricted to India but has also been reported from Texas in the U.S.A. and Venezuela in South America. The Texas root rot differs from the Indian root rot in being caused by a soil inhabiting fungus, *Phymatotrichum omnivorum* (Shear) Dugg. The pathogen produces bronzing or yellowing of the leaves about 24 hours before wilting of the plants, a condition which has not been observed in the Indian root rot. In Texas, the disease makes its appearance when the squares are being formed and seldom earlier, but in India the disease is at its height either early in the growing season as in the Punjab or late at the flowering or boll development stages as in Gujerat (Peltier, King and Samson, 1926; Vasudeva, 1935).

In Venezuela, the root rot is reported to be caused by *R. bataticola* and occurs in areas flooded by rain or by improper irrigation (Wolf, 1949). In these respects the disease appears to have a close similarity with the Indian root rot.

Though the exact losses caused by the disease have not been assessed systematically in India, Vasudeva (1942b) has reported a loss of about three per cent. in the Punjab under normal conditions. In extreme cases the damage may be as great as 90 per cent. of the crop. Figure 31 shows distribution of diseased plants in a badly affected field.

Rhizoctonia solani and *R. bataticola* have a very wide host range. Shaw (1912) has reported that the isolates of *R. solani* occurring on cowpea, cotton and groundnut can infect each other's host though the attack is usually less virulent than with their own strains. The isolate of *R. solani* found on jute, however, shows a high degree of specialization as it does not, under normal conditions, attack the above three hosts. *Rhizoctonia bataticola* occurring on cotton has also been reported to attack *Ricinus communis*, *Sesamum orientale*, *Crotalaria juncea* and *Cyamopsis psoraloides*. Isolates of the pathogen from all these plants have been found to be morphologically and pathologically similar (Prasad, 1944).

Symptoms. The first and the most prominent symptom is the complete wilting of the plant. Early in the morning one can see plants which have suddenly and completely wilted. From top to bottom every leaf droops down and it is a matter of surprise that plants looking perfectly healthy are killed outright within a day. Sometimes a wilted plant may recover during a cool night in wet weather; irrigation may also help in such a recovery though it happens very rarely. Usually when once a plant wilts, there is no recovery. The suddenness of wilting is a characteristic feature of this disease. The diseased plants occur in more or less circular areas and this is so characteristic of the disease that it is called *kundi* (a round pot) in Gujerat. Plate IXb shows heavily infected field. The stakes indicate positions of plants which have already been destroyed by the disease.

The affected plants can be easily pulled out of the ground. By removing the soil carefully around the roots of a freshly attacked plant it has been observed that except the tap root and a few secondary roots which hold the plant in the soil, all others are decayed and detached. The disease actually starts much earlier and its above-ground manifestation in the form of wilting is, therefore, a very late symptom. The tip of the root of a freshly wilted plant is slightly moist and sticky. On a white surface it leaves a yellowish stain. Plants that have recently succumbed to the disease have all their root tissues, particularly the bark, broken down into shreds (Plate IXc). On some wilted plants the yellowing and shredding may extend above the ground level. The central woody cylinder is not affected within but turns golden yellow in colour on the surface. In badly affected plants the wood becomes brown or black. Underneath the bark there is a deposit of a yellowish granular substance which may even fill the lumen of wood vessels in several cases (Vasudeva, 1935).

Etiology. The disease is caused by *R. bataticola* (Taub.) Butler and *R. solani* Kühn in the Punjab and by the the former species alone in Gujerat (Vasudeva, 1935 ; Luthra and Vasudeva, 1938 ; Uppal, 1948).

The hyphae of the two *Rhizoctonia* spp. are found in the rotten cortical tissues of the roots, and in advanced cases of rot they may extend as far as the pith. They are also found in the shredded bark and have sometimes been observed even in the xylem vessels (Butler, 1918 ; Vasudeva, 1935). The

sclerotia of the two fungi are found in abundance within the bark and dis-integrated cortical tissues of the affected plants. The sclerotia of *R. bataticola* are black, irregular in shape and have an average dimension of $105 \pm 2.3 \mu$ while those of *R. solani* are dark brown and irregular in shape and size.

Likhite, according to Uppal (1948), has reported that in Gujerat soils highest number of sclerotia of *R. bataticola* usually occur at a depth of 6 to 12 inches, whereas the number decreases at 15 to 18 inches depth. He has also noted that during the monsoon period when there is an increased vegetative activity of the mycelium, very few sclerotia are formed and this perhaps explains the absence of sclerotial formation at a certain stage by the two *Rhizoctonia* spp. under irrigated conditions in the Punjab. Late in the season, however, as the conditions become dry, appreciable number of sclerotia are formed and the optimum number is reached at the end of the cotton season.

The perfect stage of *R. solani* is *Pellicularia filamentosa* (Pat.) Rogers which is also known as *Corticium vagum* var. *solani* Burt ex Rolf or *C. solani* (Prill. & Del.) Bourd. and Galz. It has, however, not been found on the cotton plant though it has been obtained artificially on a non-living substratum (Ullstrup, 1939). *Rhizoctonia bataticola* is reported to have a pycnidial stage, *Macrophomina phaseoli* (Maubl.) Ashby, which is produced on the affected cotton roots if they are kept in moist sand at 40°C. for about three days.

Reichert and Hellinger (1947) after having studied the occurrence, morphology and parasitism of *R. bataticola* have suggested that the name *R. bataticola* should be discarded altogether. They consider that the pathogen has three different strains and suggest that the name *Macrophomina phaseoli* should be applied solely to the strains forming pycnidia only, *Sclerotium bataticola* to those forming sclerotia only, while those forming both pycnidia and sclerotia should be referred to as *Macrophomina* (*Sclerotium*) *phaseoli*.

Physiology of Causal Fungi. *Rhizoctonia solani* and *R. bataticola* have been found to be fairly fast growing fungi in culture media at 30°C. and have a very wide range of toleration to acidity and alkalinity, i.e., pH 2.4 to 9.2. *Rhizoctonia solani* produces a profuse white aerial mycelium which turns light brown with age. There are plenty of white aggregations of hyphae which later form dark brown hard sclerotia. *Rhizoctonia bataticola* also produces plenty of aerial mycelium but this later turns dark grey with age and forms numerous small black sclerotia (Vasudeva, 1936).

The two fungi are not very highly selective in their metabolism as they can grow satisfactorily on practically all the sources of carbon and nitrogen. Sodium chloride, magnesium sulphate and ferric chloride are not of great importance but carbon, nitrogen and phosphorus materially affect the growth of the two fungi. They do not show any appreciable growth under highly anaerobic conditions. Their growth is markedly retarded at 25 per cent. concentration of carbon dioxide (Vasudeva, 1936; Luthra, Vasudeva and Ashraf, 1940).

The thermal death points of *R. bataticola* and *R. solani* have been found to be fairly high, being 68° and 60°C., respectively (Vasudeva, 1936). Among the various substances which can check the growth of the two fungi mercuric chloride (0.09%), copper sulphate (0.3%) and phenol (0.5%) have been found to be quite effective (Vasudeva, 1937a).

The intensity of sclerotia formation by the two *Rhizoctonia* spp. depends on the composition, concentration, depth and pH value of the medium. Sugar, nitrogen and phosphate have been shown to be very essential for the sclerotia formation in culture medium. When ammonium salts $[(\text{NH}_4)_2\text{SO}_4 \text{ or } \text{NH}_4 \text{ Cl}]$ are used as source of nitrogen, sclerotia formed are larger in size than those formed with peptone. Formation of sclerotia is comparatively poorer with magnesium phosphate than with potassium phosphate or potassium dihydrogen phosphate. This is probably due to the absence of potassium. *Rhizoctonia bataticola* forms abundant sclerotia in media with a pH range of 3.3 to 7.8, whereas at pH 8 there is a considerable fall in their formation though their size is increased. For *R. solani* pH 6.8 is the optimum for sclerotial development. Light does not seem to have any effect on the formation of sclerotia of both the fungi. The sclerotia *R. solani* and *R. bataticola* lose their viability when exposed to three per cent. NH_4OH solution for five minutes and four per cent. solution for 10 minutes, respectively. Hydrocyanic acid gas kills the sclerotia of both the fungi when applied for 45 minutes under moist condition, whereas sclerotia exposed to the gas under dry condition have been found to be viable even after a week (Vasudeva, 1937a).

Predisposing Factors. *Rhizoctonia solani* and *R. bataticola* cause heavy infection at 20 and 15 per cent. soil moisture, respectively. At five per cent. soil moisture both the fungi are unable to parasitise the host. An adequate supply of water in early part of the season, when the plants are about six weeks old, favours the development of the disease and within a fortnight the mortality of the plants reaches its optimum (Vasudeva, 1937b).

The plants suffer highest mortality from *R. solani* and *R. bataticola* at soil temperatures of 35° and 39° C., respectively. Although *R. bataticola* is actively parasitic over a range of temperatures varying from 25° to 39° C. there is a fall, noticeable in the parasitic activity of *R. solani* above and below 35°C. (Vasudeva and Ashraf, 1939).

The effect of soil temperature on the disease incidence has been correlated with periodicity of the disease in irrigated areas of the Punjab (Vasudeva, 1937b). The attack starts in June and within a fortnight optimum percentage of mortality is reached. The disease, however, continues to be severe throughout July. In August, the death rate gradually declines and the disease almost ceases by the end of September. Figure 32 gives the progress of the disease in the irrigated areas of the Punjab (Vasudeva, 1935).

The relationship of soil temperature and soil moisture to disease incidence is obviously well defined. In the non-irrigated areas of the Punjab

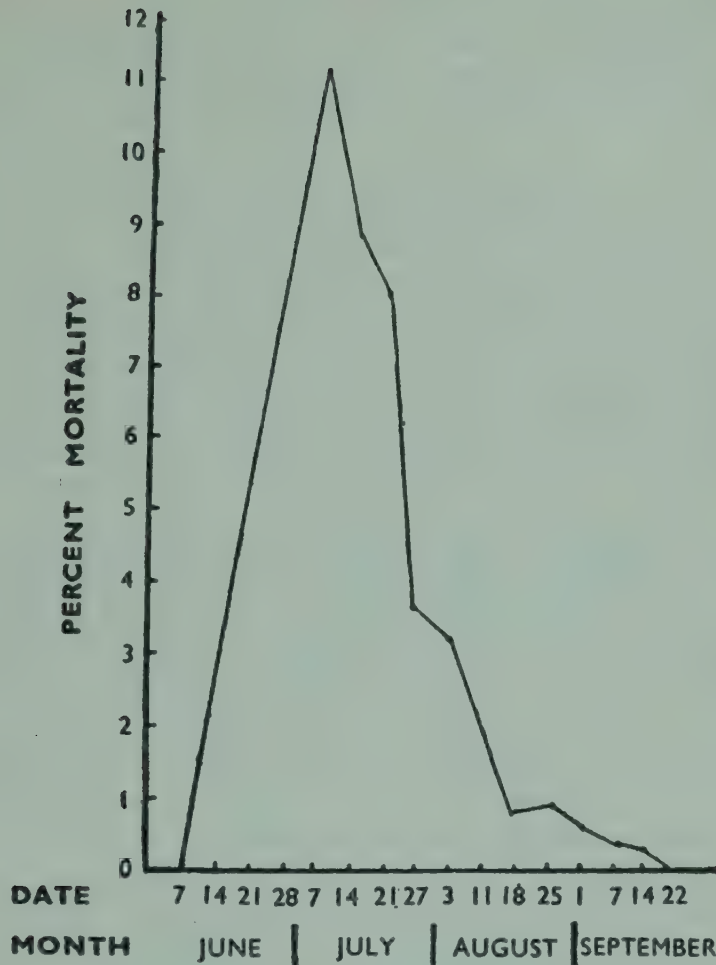


Fig. 32. Progress of Disease During Different Months

soil temperature during the growing period of cotton is very high and, therefore, unfavourable for parasitic activity. That is why probably no root rot symptoms are observed in such areas though the two fungi have been isolated from roots of the plants. In Gujarat the maximum damage occurs at the flowering or boll development stages.

There is no difference in the texture and chemical composition of healthy and sick soils except that the latter contain a high amount of acid soluble calcium and have a higher Ca: Mg ratio (Vasudeva and Ashraf, 1939). The chemical analysis of diseased and healthy plants has shown that although the roots of diseased plants contain a higher amount of calcium, the percentage of calcium in the diseased plant as a whole is lower than in a healthy plant (Vasudeva and Rafique, 1939). This shows that in diseased plants the roots do not transport calcium to upper parts although it is taken up from the soil. Hydrogen-ion concentration of the soil appears to have no effect on the disease incidence (Vasudeva and Ashraf, 1939).

The parasitic activity of *R. solani* is increased when it grows in combina-

tion with *Fusarium* sp., *Alternaria* sp. and *Helminthosporium* sp., while the association of these fungi with *R. bataticola* does not produce any significant difference in its parasitic activity. The parasitic activity of *R. solani* and *R. bataticola* is greater when acting together rather than when parasitising singly (Vasudeva, 1936).

The presence of *Trichoderma lignorum* and *Aspergillus niger* in the inoculum of *R. bataticola* and *R. solani* interferes with the growth of latter fungi by dissolving their hyphae (Vasudeva and Sikka, 1941). The activity of filtrates of the two *Rhizoctonia* spp. with respect to their power of producing wilt conditions when roots are dipped into them is reduced when these fungi are grown in mixture with *Trichoderma lignorum* and *Aspergillus niger*. The toxic principle in 60 days old state can be easily destroyed by heating (Vasudeva and Sikka, 1941).

Physiology of Diseased Plant. It has been observed that the diseased plants remain considerably warmer as compared to the healthy ones. The rate of respiration is lower in diseased plants than in healthy ones. The increase in temperature of the diseased plants is probably due to defective root absorption as a result of which the moisture supply of leaves is curtailed and the heat incident is not dissipated, resulting in warming up of the leaves. On the other hand in healthy plants, due to active transpiration, the leaves remain comparatively cooler (Vasudeva, 1944).

A chemical analysis of the diseased and healthy plants has shown that reducing sugars and sucrose are more in the leaf, stem, and root of diseased plants than in the corresponding parts of healthy plants in the same field. Total and ammonical nitrogen, calcium to potassium ratio, total sugar to potassium ratio and iron are considerably higher in diseased than in healthy plants. There is no significant difference in the phosphorus contents of diseased and healthy plants. The nitrate nitrogen, potassium, sodium and calcium contents of the diseased plants are lower than those of healthy plants. The respective ratios of iron and calcium in the leaf to those in root are significantly lower in diseased than in healthy plants. This shows that although there appears to be an accumulation of these two elements in roots of diseased plants, their stems and leaves are unable to make use of them. Whether this condition is the result of disease or *vice versa* requires further investigation. The ratio of potassium in the leaf to potassium in root is higher in diseased than in healthy plants (Vasudeva and Rafique, 1939).

Control Measures. The disease affects both the American and indigenous varieties of cotton. Luthra and Vasudeva (1941) have tested a large number of strains imported from America and other countries but none of them have shown any appreciable resistance to the disease.

Fumigation of the infected soil by means of chemicals is unsatisfactory because of the cost involved and the possibility of disinfectant proving ineffec-

tive when applied under field conditions. It has been observed by Vasudeva (1945) that the disease incidence in plots treated with para-dichlorobenzene is reduced but germination is delayed and the plants remain comparatively smaller and stunted. The yield of seed cotton in the treated plots is lower than that obtained from the controls.

Removal of diseased plant debris, addition of different chemical fertilizers, trace elements or farm yard manure and flooding of fields do not in any way reduce the disease incidence (Vasudeva, 1945).

Tillage does not seem to have any effect on the disease incidence, there being no difference in the mortality of plants in plots where cotton is cropped continuously or tillage is carried out during summer or winter or there is a 12-month or 24-month tillage. The incidence of the disease, however, is greatly reduced by trenching up to a depth of six feet, but this method of control is laborious and impracticable (Vasudeva, 1945).

Adjustment of Sowing Date: As already stated, *R. solani* and *R. bataticola* show a well marked periodicity in their parasitic activity in the irrigated areas of the Punjab. The two fungi are more active and cause maximum

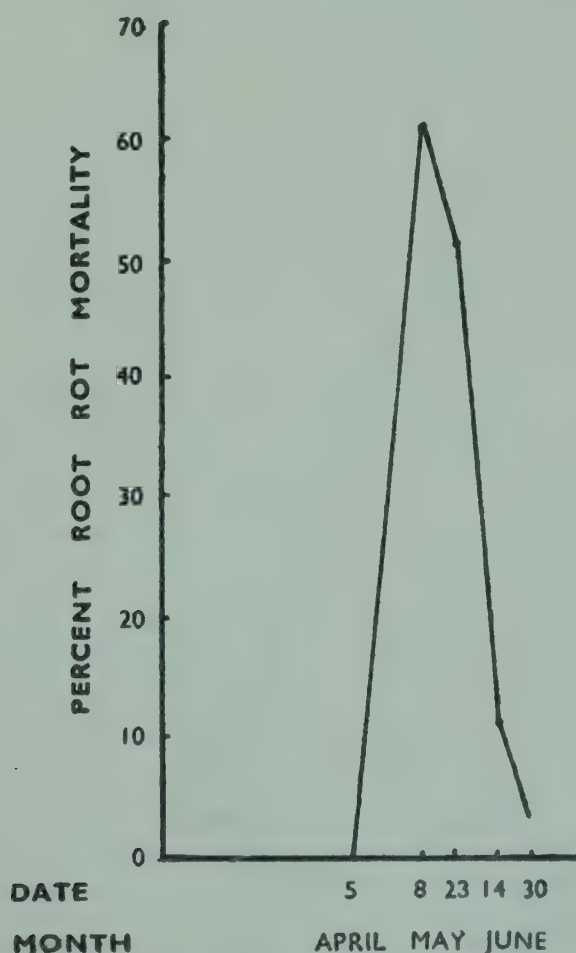


Fig. 33. Effect of Sowing Date on the Incidence of Root Rot

damage during June and July. Experiments conducted by Vasudeva (1943) have shown that maximum damage is caused by the disease in May-sown crop, whereas there is a marked reduction in loss in sowings carried out in the first week of April or the end of June, obviously as a result of escaping the period of optimum activity of the casual fungi. The yields of early and late sown cottons are also satisfactory. In the case of late sowings yield can, however, be further made up by close planting. Figure 33 shows the effect of sowing date on the incidence of the disease (Vasudeva, 1943).

Intercropping with other Plants: The incidence of the disease is reduced by intercropping cotton with *moth* (*Phaseolus aconitifolius* Jacq.) which offers protection to the cotton plants and is instrumental in lowering the soil temperature which is unfavourable for parasitic activity of the casual organisms (Plate X a). *Moth* is sown in between the cotton rows on the same day on which cotton is planted. It has been noted that *moth* neither shades nor adversely affects the growth of the cotton plants. Figure 34 shows the effect of mixed cropping on root rot mortality (Vasudeva, 1941). Padwick (1942), while emphasizing the importance of the effectiveness, of this method, states that, "the extraordinary beneficial effects of this method of control of cotton root rot have to be seen to be believed."

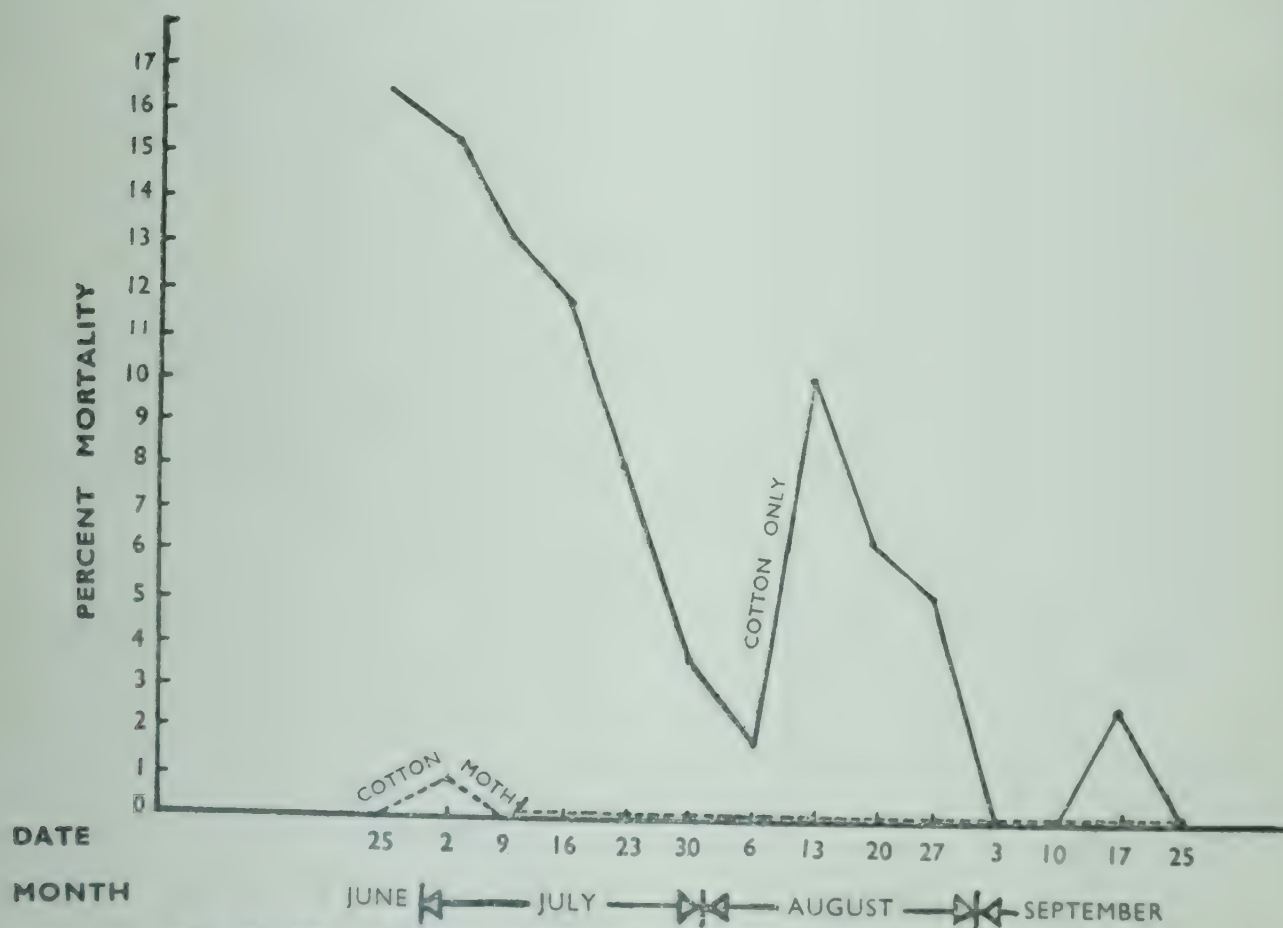


Fig. 34. Effect of Intercropping Cotton with *Moth* on the Incidence of Disease

Adjustment of sowing date and mixed cropping with *Phaseolus aconitifolius* are obviously the two simplest and most effective methods for the control of the disease. If the cropping pattern permits, adjustment of sowing date can be easily adopted, failing which intercropping with *Phaseolus aconitifolius* is infallible and easy to practice and also it provides green fodder for the cattle in those areas where no fodder is available during that period.

ANTHRACNOSE

The disease is widely prevalent in all the eastern humid cotton growing States of the U.S.A. but is rare in the drier areas. It has also been reported from Burma, the West Indies, Egypt, South and West Africa, Brazil, Bulgaria and Trans-Caucasia. In India, it was first reported from Pusa in Bihar (Butler, 1918) and since then has been recorded from Madras (Sundararaman, 1927, 1928, 1929, 1930, 1932), Madhya Pradesh (Dastur, 1934; Ramakrishnan 1946), Bombay (Uppal, Patel and Kamat, 1935) and Bengal (Uppal, 1948).

In the United States the losses caused by the boll rot phase of the disease were estimated before 1920 to be between 10 and 70 per cent. of the crop. In recent years, however, due to the introduction of early maturing small varieties with less vegetative growth, the losses have been considerably reduced. Similarly, losses caused by the seedling blight before the introduction of seed disinfectants were also very heavy (Smith, 1953). In Madhya Pradesh, the disease though of minor importance may at times become quite destructive, particularly in wet years. In 1931, it appeared in an epiphytotic form. In Madras, the disease is quite serious and causes on an average a loss of about 48 per cent. of seed cotton. The disease, however, is of minor importance in other parts of the country and occurs there only occasionally.

Symptoms. The disease affects the seedlings, bracts and bolls. On the cotyledons and primary leaves of the seedlings it forms small, reddish or light coloured diseased spots. The lesions at the collar are elongated and reddish brown in colour. They may either be on one side of the stem or may engirdle it. Sometimes the lesions may extend down to the roots. Such a seedling blight usually results in the death of the plants. In mature seedlings, however, the attack on the woody stem, breaks the bark into shreds and the wood becomes discoloured brown, usually resulting in the wilting of the seedlings.

In case of mature plants, the stems are frequently attacked through the wounds or when the plants are rendered weak due to some other causes. Usually the leaves are only slightly attacked and the infection is mostly restricted to the sickly or wounded leaves.

The bolls are affected by the disease at any stage of their growth. The disease first appears as small, water-soaked, circular, slightly depressed, reddish brown spots. As the lesions grow in size, their centres become black

(Plate Xb). Quite often the spots have a tendency to coalesce and form larger diseased areas. Diseased spots are also formed on the bracts where they rapidly enlarge and may extend to the bolls. The fungus gains entry to the bolls either through the corolla, bacterial blight lesions, insect wounds or sutures separating the loculi. It may also directly penetrate the uninjured surface. On entering the bolls the fungus rapidly invades the lint and seeds. The lint is stained yellow or brown and becomes clumped into a solid brittle mass of fibres. If attack occurs before the bolls are mature there is much deformity of the tissues. Such bolls dry up prematurely, cease to grow and crack. The lint of such bolls is usually ruined by the growth of the pathogen and other fungi. Marsh and his associates (Smith, 1953) have reported that during wet weather the lint and seed of the bolls which are just beginning to open, are invaded directly by the pathogen and *Diplodia gossypina* Cke. producing the 'tight lock' symptoms.

The seed is invaded by the pathogen through the lint, the hyphae in such case reach the outer integument. The fungus may also enter through the placenta and reach the inner integument and embryo. Badly affected seeds are light, brown, poorly developed and usually do not germinate.

Etiology. In India, the disease is caused by *Colletotrichum capsici* (Syd.) Butler and Bisby (= *C. indicum* Dast.) except in Bombay where it is reported to be caused by *C. gossypii* Southw. In other countries it is caused by *C. gossypii*.

Colletotrichum capsici forms numerous acervuli on the affected seedlings and bolls. The conidiophores are hyaline, slightly curved, broadly rounded at the apex and flat at the base and measure 7.7-13.2 by 1.6-2.7 μ . Numerous falcate and hyaline conidia are abstricted from their tips. On an average they measure 20-22.5 by 2.5 μ . The setae are thick-walled, with many septa, dark coloured but pale at the base and apex, and measure 76.5-125.5 by 3.8-7.6 μ .

In the case of *C. gossypii*, the conidiophores may arise in acervuli or from the immersed hyphae, independently of stromata. They are hyaline, usually unseptate but sometimes with one or two septa and about twice the length of conidia. Conidia are unicellular, straight or sometimes curved, nearly oblong and measure 11-20 by 4-9 μ . They are formed both on the conidiophores and setae. Those which arise on the setae are usually small and oval. The setae are dark brown below, colourless above, septate, straight or flexuous, rarely branched and measure 100-250 μ in length.

The perfect stage of *C. capsici* is not known while that of *C. gossypii* is *Glomerella gossypii* Edgerton, an ascomyceteous fungus. It has been reported on the diseased bolls in the United States. The perithecia are immersed, dark, roundish or pear-shaped and sometimes with a prominent beak. The asci are numerous and measure 55-70 by 10-14 μ . The ascospores are ellip-

tical, sometimes slightly curved, hyaline, unicellular and measure 12-20 by 5-8 μ . Paraphyses are numerous, long and slender (Butler, 1918).

Colletotrichum capsici attacks *G. herbaceum* and *G. arboreum*, while the Madras strain of the fungus can infect only *G. herbaceum* and the two common weeds, *Aristolochia bracteata* and *Hibiscus diversifolius*.

The pathogen perennates as mycelium in the seeds or as spores on their surface. It may also perpetuate on the old rotten bolls and other plant remains in the field.

The progress of the disease is much more in moist than in dry weather. Uppal (1948) has reported that in Madras, if there are rains during the first three weeks after emergence of the plants, seedling blight is very common and the boll rot is also influenced by the unusual rains during December and January.

Control Measures. Surface disinfection of the seed with Ceresan, Ceresan M, Zinc trichlorophenate (Dow 9-B) and sulphur is quite effective in largely eliminating the surface-borne spores. Dastur (1934) has obtained good control of the disease by immersing the seed in 0.25 per cent. Uspulum for one hour. Since the spores of the pathogen cannot retain their viability for a long period, planting of two to three year old seed is often recommended. Sowing of the disease-free seed from a healthy crop is a simple and economic method of control.

One year rotation and ploughing under the diseased debris after harvesting the crop are quite effective in eliminating the source of primary infection.

Defoliation of the plants by dusting with calcium cyanamide at the rate of 30 lb. per acre reduces the humidity round the bolls and results in the rapid drying of the bolls and lint after the rains, thereby reducing the boll rot phase of the disease (Smith, 1953).

Removal or destruction of the collateral hosts of the pathogen aids in controlling the disease.

Spraying the seedlings with Bordeaux mixture also helps in checking the disease. Two applications of spray are often recommended (Sundararaman, 1929, 1932).

SORE SHIN OR DRY ROT

The disease occurs throughout the cotton belt in the United States and is considered to be the most serious seedling disease of cotton, particularly in the western States. It has also been reported from Egypt where the damage done by the disease often necessitates re-sowing. In the Sudan, due to unfavourable high temperatures at the sowing time, the disease is negligible. Only recently (1952), it has been reported from Morocco (Butler and Jones, 1949; Miege, 1952; Neal, 1953).

In India, the disease has been reported from Madhya Pradesh and Hyderabad, and is common in Khandesh (Bombay State) (Dastur, 1931; Sawhney and Narayanayya, 1932, Uppal, 1948).

Symptoms. The disease affects the seedlings and young plants. Plants less than 10 to 12 weeks old are usually the most susceptible. It can be easily distinguished from 'damping off' by the fact that the stem of infected seedlings remains upright and the diseased part is not water-soaked. The affected seedlings can be easily pulled out with the tap root intact.

The pathogen attacks the collar, roots and leaves. The lesions on the collar occur near the soil level and are first pale brown or reddish brown, then turn dark brown and ultimately become almost black. In severe attack the plants fall over and die. The cotyledons when completely affected are shrunk, smaller in size and hang limply. Slightly affected cotyledons do not turn yellow and appear as if these have been badly pinched between the thumb and the fore finger. Usually only one cotyledon is affected. If the stem of the young plant becomes woody at the time of infection, the shredding of the affected bark is commonly observed. The affected part of the tap root is thinner than the healthy parts because the former shrinks up due to drying of the infected cortical tissues.

Sometimes the seedlings are liable to infection before the primary leaves have emerged from the seed coat, thus hindering in the germination of the seed.

The foliage leaves when infected become somewhat bleached and later turn brown. They become shrunk, crispy and brittle, and have a tendency to roll inwards from the tip towards the petiole. The infection remains restricted to the leaves and does not spread to the stem. Ultimately the affected leaves fall off and the plant puts forth new shoots and buds. The infection from leaf to leaf takes place by the contact of diseased leaf with a healthy one, especially during rains when the two leaves get stuck to each other by means of a film of water in between them. Spiders have also been found to be responsible for carrying the infection from one leaf to another.

Mature plants, as a rule, are not affected by the disease. Cases of three to four months old plants with infection restricted to the leaves have, however, been recorded. Such plants on shedding off the infected leaves put forth new leaves and appear quite healthy. In water-logged fields, the disease may cause appreciable damage to mature plants as well. The bark at the collar of badly affected plants breaks up into shreds and the wood becomes discoloured brown or black. The affected part of the tap root becomes discoloured brown but unlike the seedling blight there is no shrinkage. The infection of mature plants may also occur after heavy rains when the wet soil dries up rapidly and forms a hard cake round the collar which naturally is pressed tightly and so becomes flattened with its bark cracking longitudinally. The fungus enters the host through these cracks and ulti-

mately kills the plant. Infection of the plants may also occur through wounds caused by insects and agricultural implements.

Etiology. The disease is caused by *Rhizoctonia bataticola* (Taub.) Butler in India and by *R. solani* Kühn in other countries. Occasionally *R. solani* has also been recorded as the cause of the disease in this country.

The pathogen can cause infection of the seedlings only under limited soil conditions. All those factors which delay quick germination (i.e., coming up of the cotyledons to surface of the soil) are favourable for the infection of the seedlings. Even under very favourable conditions for seed germination, some seeds germinate slowly than the rest. Such seedlings are naturally more likely to be attacked by the fungus. Sometimes after the sowing of the seed there is a long break of rains and under such conditions the young seedlings take a long period to reach the soil surface. At times there are heavy rains after the sowing of the seed with the result that the top surface of the soil forms a hard crust which the underground seedlings cannot easily break through. Under unfavourable soil conditions a loss of as much as 30 per cent. of the seedlings has often been recorded. The incidence of the disease is much influenced by soil temperature and particularly the rainfall.

In Egypt where the disease is caused by *R. solani*, the temperature at the sowing time is the determining factor for the infection of the seedlings. It has been observed that in both the parasite and the host there is an accelerated growth with the rise of the temperature which, however, ceases at 37° C. For the cotton plant the optimum temperature for its growth and for the formation of defensive cork is 33° C. The fungus almost ceases to grow at 33° to 37° C. because of the production of auto-toxic substances produced by its own metabolism. At lower temperatures these toxic substances are produced at a much slower rate with the result that the fungus grows normally and thus accounts for the appearance of the disease in the early sown crop (February and March) when the prevailing temperatures vary from 20° to 25° C. In the late sown crop (April and May) the disease appears in a mild form, i.e., in the form of scars, because of the prevailing temperature of about 33° C. which as already stated, is not congenial for the development of the fungus (Balls, 1908).

In the United States, Neal (1953) reports that the pathogen attacks the cotton plant in weather when the conditions are favourable to the fungus but unfavourable to the host.

Control Measures. A number of fungicides have been tested for the possible control of the disease, but none of them has given satisfactory results. Anyhow, there are some cultural practices, as detailed below, which, if followed, can reduce the incidence of the disease.

1. Certified seed should be sown which has been treated for the control of seed-borne diseases.

2. For speeding up germination, acid delinted or re-ginned seed should only be planted. Fertilizers may also be added to the soil so as to give a vigorous start to the seedlings.
3. Seed beds should be thoroughly prepared so that the rows are well pulverized at the surface, firm beneath and about four to six inches raised with a view to obtaining good drainage.
4. Very early sowing should be avoided unless there has been sufficient rain so that the soil moisture is enough for rapid germination of the seed.

In Egypt and the U.S.A., delayed sowings until the soil warms up have resulted in a considerable reduction of the disease. Early planting causes heavy infection because of the prevailing favourable cool nights and moist weather.

5. If after sowing there has been a rainfall so that the surface soil has formed a hard crust after drying, this crust should be broken up.

DAMPING OFF OF SEEDLINGS

The disease is of minor importance and occurs only sporadically. Andrews and Clouston (1936) and Mahmud (1951) have recorded *Pythium debaryanum* Hesse on cotton seedlings from the Sudan and India (Madhya Pradesh), respectively. Mitra (1929), on the other hand, has reported the disease to be caused by *Phytophthora parasitica* Dast. in Bihar (India). In Madhya Pradesh, Dastur (1931), however, has reported the disease to be caused by *Pythium* and *Phytophthora* spp.

Symptoms. *Pythium debaryanum* attacks two or three to twelve days old seedlings and forms a yellowish discolouration on the hypocotyl at or just below the ground level. The discoloured areas then become soft in a day or two and the seedlings ultimately fall over at this point.

Phytophthora parasitica appears on young seedlings not more than two to three weeks old. Irregular, water-soaked spots appear on the cotyledons and primary leaves. Later they coalesce and involve the whole leaf. In severe cases of attack, the disease spreads to the petioles with the result that the leaves hang down and finally fall off. Ultimately the fungus invades the growing points of the seedlings resulting in their sudden collapse. When the pathogen attacks the seedlings at the collar region the latter becomes soft and rotten. The seedlings ultimately topple over at or near the ground level whereas the underground parts become decayed and water-soaked. Such affected seedlings cannot be uprooted with the tap root intact (Uppal, 1948).

The disease appears only when the conditions are very humid and the soil is water-logged. Sometimes the attacked seedlings die before they emerge from the soil.

Etiology. *Pythium debaryanum* forms terminal or intercalary sporangia which are usually spherical when terminal and ovate, barrel or saucer-shaped

when intercalary and measure $12.0-32.5 \mu$ in diameter. They either produce zoospores or germinate directly by forming germ tubes. The zoospores are round, $7.2-13.2 \mu$ in diameter and germinate by germ tubes. The oogonia are smooth, thin-walled, terminal or intercalary, spherical or slightly ovate and measure $15.3-25.8 \mu$ in diameter. The antheridia are terminal or intercalary, monoclinal or dichlinal, broadly club-shaped and straight, crook-necked or arched. Usually one, occasionally two or three, and in rare cases even four antheridia are attached to a single oogonium. The oospores are spherical, hyaline, smooth and measure $14.5-22.8 \mu$ in diameter (Mahmud, 1951).

Phytophthora parasitica forms slender, unbranched and $100-300 \mu$ long sporangiophores. Sporangia are terminal, roundish or ovoid, papillate and measure $25-50$ by $20-40 \mu$. They either produce zoospores or germinate directly by forming germ tubes. The chlamydospores are yellowish, thick-walled, round and measure $20-60 \mu$. The antheridia are amphigynous. The oospores which are formed only in culture are globose and measure $15-20 \mu$ in diameter (Dastur, 1913).

SCLEROTIUM WILT

The disease has been reported from the tropical and sub-tropical countries, especially from the southern parts of the United States where it is reported to be quite serious. It has also been recorded from New South Wales, Maryland and El Salvador. In India, the disease occurs in the States of Bombay and Madhya Pradesh where it is of minor importance and restricted to water-logged fields, particularly during years of heavy rainfall (Uppal, 1932; Magee, 1947; Crandall, Abrego and Patino, 1951; Epps, Patterson and Freeman, 1951; Brooks, 1953).

The disease has also been reported to affect bean, maize, potato, tomato, cabbage, rhubarb, etc., in the United States and corms of the Arum Lily and bulbs of *Amaryllis* in England. In the tropics it affects the groundnut, sugarcane, black pepper and sweet potato.

Symptoms. The pathogen usually attacks the plants from the soil near ground level, resulting in the rapid decay of the roots on which a large number of small sclerotia are observed. Young plants when affected succumb to the disease and a white mass of fungal mycelium with numerous sclerotia appears at the base of the stem. In the field, the disease appears at a few scattered spots and then spreads centrifugally. If the older plants are attacked, they do not die immediately but first turn yellow and then get wilted.

Etiology. The disease is caused by *Sclerotium rolfsii* Sacc. The mycelium grows in the form of white strands of fan-shaped expansions and forms small sclerotia which are black and about the size of mustard seed. According to Taubenhaus (1919), the pathogen does not seem to have any distinct physiologic races. This view, however, is not shared by Epps, Patterson and Freeman (1951) who believe that four different strains of the pathogen can be

easily distinguished on the basis of their behaviour in agar plate culture. These strains also show some minor, nevertheless, consistent difference in their virulence as measured by the rapidity with which they kill the plant. Besides these differences, one of the strains forms distinctly different type of sclerotial bodies.

The perfect stage of the fungus, *Corticium rolfsii* Curzi, a basidiomycetous fungus, has been obtained in cultures containing onion, asparagine and proteose peptone. The basidia are produced in crusts, 6 to 12 mm. in diameter, on white cushions of dense mycelium. They are clavate, colourless, septate at the base and sometimes furnished with two, three or four sterigmata. Most of the basidia are sterile. The basidiospores are obovate, globose or slightly cylindrical and measure $4.9-9.4 \mu$ (Mundkur, 1934).

Control Measures. The losses caused by the disease can be reduced by application of ammonium sulphate at the rate of four to five cwt. per acre (Magee, 1947).

In some countries rotation with wheat and barley in winter and autumn months has been reported to reduce the carry-over of the disease.

INTERNAL BOLL DISEASE

Stigmatomycosis or the internal boll disease is a serious and widespread disease of cotton in tropical and sub-tropical regions. In India, it was first reported by Dastur and Singh (1930) from Nagpur in Madhya Pradesh.

Symptoms. The disease is characterised by partial or complete destruction of the seed, discolouration and breaking of the lint and sometimes by premature fall of the bolls.

The punctures made by insects through which the disease is transmitted are commonly seen on the affected bolls. Below these punctures the lint is generally destroyed but in the surrounding loculi it is usually discoloured. In the beginning the affected lint shows a slight yellowish tinge which finally turns scabbe brown. The walls and central canals of the cell hairs become yellowish brown but in Nyasaland, as reported by Marsh (1925), there is no such discolouration.

The affected seed may get shrivelled or discoloured. Sometimes, it may have an outward healthy appearance but in such cases the fungus can be easily detected in the embryos.

One or two week old bolls, when infected, fall off prematurely or get aborted. Their growth is completely arrested, the seeds are killed and their lint is often reduced to dark papery membrane. In three to four week old bolls, the lint is severely stained but not completely broken down. Five to seven week old bolls show little effect, if any, on boll size and opening. The lint is not broken down but is moderately stained. Eight to nine week old bolls show only traces of light discolouration and slight immaturity (Pearson, 1947).

The artificial inoculation of bolls with sterile water alone can also produce disease symptoms, the severity of infection depending upon the age of the bolls and quantity of water introduced (Pearson, 1947).

Etiology. The disease is caused by *Nematospora nagpuri* Dast. in India and by *N. gossypii* Ashby & Now. and *N. coryli* Peglion in other countries. The pathogen is mostly found, chiefly in the ascigerous stage, on the discoloured lint.

The Indian *Nematospora* forms very slender hyphae on glucose agar medium. The yeast-like cells produced by the fungus may be small, lonzenge-shaped with many buds remaining attached to the mother cell, or large and globose from which long elliptical ascus mother cells are developed. The asci are colourless, elliptical with broad rounded ends and sometimes with a small depression in the centre. They measure 42-57 by 7-12 μ and contain usually eight but occasionally two or four ascospores which are bicelled, long, narrow and with pointed apices, the lower end being drawn into a flagelliform appendage. They measure usually 33-40 by 2-2.5 μ , the appendage being 20-30 μ in length. On germination the ascospores give rise to a globose swelling near the septum from which yeast-like cells are generally developed. Sometimes the germ tubes grow into small hyphae which bear yeast-like cells laterally and apically (Dastur and Singh, 1930).

Nematospora nagpuri differs from the two foreign species, *N. gossypii* and *N. coryli*, in forming encrusted, cauliflower-like pure white growth on potato slabs as compared to the flat and feathery development of the other two species. The Indian species also differs from the other two species in the size of asci, ascospores and appendages (Dastur and Singh, 1930).

Transmission of Disease. The disease is transmitted and spread by the stainers, *Dysdercus* spp. Young bolls punctured by the uninfected stainers and showing no trace of *Nematospora* or pathogenic bacteria develop lethal effects similar to those produced by inoculation with sterile water alone. These effects, however, differ from those accompanying *Nematospora* chiefly in being much more localised and in the limited staining of lint (Pearson, 1947).

Male stainers (*Dysdercus nigrofasciatus*) have a marked preference for cotton bolls when they are two to three weeks old. At this stage the bolls have a high moisture content and are visited by stainers, perhaps in search of water (Rainey, 1948).

Control Measures. The disease can be controlled by so adjusting the date of sowing that development of bolls occurs at the time when insect vectors are least abundant. Eradication of other hosts of stainers help in the reduction of insect population and thereby reduce the incidence of the disease.

GREY MILDEW

The disease is known to occur in the United States, the West Indies, South Africa, Middle East, Brazil and Egypt (Butler, 1918; Viegas, 1946;

Khabiri, 1952; Blank, 1953; Bigi, 1954). In India it has been reported from Madras, Bombay and Madhya Pradesh. It occurs chiefly in low lying moist localities and is of minor importance though in Madhya Pradesh it sometimes becomes quite serious in wet years.

Symptoms. The disease usually appears when the plants are reaching maturity. Irregular, angular, pale translucent spots, measuring 1 to 10 mm. (usually 3 to 4 mm.) in diameter and bordered by the veinlets, appear on the older leaves. A frosty or mildew growth consisting of conidiophores of the fungus appears on the under-surface or occasionally on the upper surface of the affected leaves. As the infection progresses, the leaves become yellowish brown and finally fall off prematurely (Butler, 1918).

Etiology. The disease is caused by *Ramularia areola* Atk. The mycelium is endophytic and restricted to the disease spots. The conidiophores emerge as short, hyaline clusters of parallel hyphae, measuring 50-150 by 4.5-7 μ . They branch only at the base and form prominent angular processes on the sides. The conidia are colourless, irregularly oblong and with abruptly pointed but sometimes rounded or flattened ends. They are either unicellular or one to three septate and measure 10-35 by 4-5 μ in diameter. They are formed at the tips and the lateral projections of the conidiophore clusters. In the beginning they are formed in chains acropetally but later they may occur singly.

ASCOCHYTA BLIGHT

The disease is also known as wet weather blight or wet weather canker. It occurs in all the cotton growing tracts of the United States and has also been reported from Belgian Congo (Steyaert, 1948), Tanganyika (Wallace, 1948) and LuBaga (Prentice, 1948). In India, Sydow and Butler (1916) have recorded it from Kashmir.

Three to eight week old plants are highly susceptible to the disease. Serious losses have been recorded in the United States by reduction in the stand of the young crop during moist cool weather when the environmental conditions are unfavourable for the growth of the plants. Stem canker symptoms, no doubt, are very characteristic but do not cause much damage. Minor losses are caused by blighting of the leaves, partial defoliation of older plants and rotting of the bolls (Smith, 1953).

Symptoms. The disease first appears as small, circular, white, purple ringed spots on the cotyledons and the lower leaves. As the spots grow in size, they coalesce, become brown and rough; the purple ring disappears and the diseased tissues often fall off. The growth of the plants becomes stunted and there is often defoliation of the cotyledons and leaves. Sometimes there is girdling of the stem resulting in the death of the terminal bud and adjacent stem tissues. The seedling blight is the most destructive phase of the disease and often causes reduction in the stand of the crop (Blank, 1953; Smith, 1953).

Conspicuous dark brown cankers, about half inch to an inch in length are formed at the branch axils and encircle the stipules. Sometimes such cankers may kill the affected branches but usually they cause very little damage. On the bolls, rough, circular and brownish lesions cause their rotting. The seed and lint are also attacked and destroyed.

The disease is usually observed during long periods of rain and cool weather but when the conditions become dry and hot, it is checked (Blank, 1953; Smith, 1953).

Etiology. The disease is caused by *Ascochyta gossypii* Syd. Pycnidia are produced irregularly or in concentric rings either only on the upper surface or on the lower side as well. They are oblong to globose, pale brown and 80-100 μ in diameter. The ostiole is round and protruding. Spores are numerous, oblong or slightly cylindrical, bicelled, hyaline and measure 8-10 by 2.5-4 μ (Blank, 1953; Sydow and Butler, 1916). The pathogen is known to produce a number of strains in the United States which can be distinguished from each other by the colour, amount of aerial mycelium, growth rate and presence or absence of fertile pycnidia (Thompson, 1950).

The fungus over-winters in the form of pycnidia on the surface of the seed or in the plant remains (Smith, 1953; Thompson, 1950).

Miller (1953) has reported the association of thrips or *Rhizoctonia solani* or both with the disease in North Georgia. In North Carolina, the pathogen has been reported to infect tobacco, *Abelmoschus esculentus*, *Phaseolus vulgaris*, *P. limensis*, hollyhock, soyabean, chilli and egg plants (Crossan, 1953; Holdeman and Graham, 1952).

Control Measures. The following measures are found effective :

1. Rotation with other crops is quite helpful in checking the primary infection.
2. Burying of the plant debris by deep ploughing immediately after harvest will eliminate the source of infection to a considerable extent.
3. Seed disinfection.
4. Miller (1953) has successfully controlled the disease in North Georgia by dusting the plants with seven per cent. tribasic CuSO_4 + five per cent. D.D.T. The first dusting was given when the plants had fully emerged from the soil, while subsequent dustings were given at four weekly intervals at the rate of 20 lb. per acre.

CERCOSPORA LEAF SPOT

The disease has been reported from the United States, the West Indies, Egypt and China. In India, it occurs in Bihar, Uttar Pradesh and the Punjab. It is of minor importance except in China where it causes much damage (Butler, 1918; Sydow and McRae, 1929).

Symptoms. The disease affects the young plants only if the environmental conditions are unfavourable for plant growth, otherwise it usually

affects the older leaves of mature plants. The spots are round or irregular in shape, yellowish brown, with purple, dark brown or blackish borders and white centres. There is sometimes coalescing of the adjacent diseased spots. The white centres finally fall off leaving a ragged appearance. Severely affected leaves become pale in colour and finally fall off (Butler, 1918; Blank, 1953).

In the United States and India, the disease usually appears on the older leaves but spreads to the whole plant if the environments are unfavourable for the growth of the plants. In the West Indies, it affects only the sickly leaves.

Etiology. The disease is caused by *Cercospora gossypina* Cke.

The mycelium of the fungus is intercellular and is restricted to the diseased spots. The hyphae get accumulated as small stromatic masses near the surface. The conidiophores arise in clusters from these masses, usually through the stomata. They are flexuous, dark brown, septate, irregularly bent near the tip and measure usually $150\ \mu$ in length. The conidia are long, slender, curved, narrow above and round below and almost hyaline. They are five to seven septate and measure $70-180$ by $3\ \mu$. There is much variation in the size of conidiophores and conidia depending on the humidity and temperature prevailing during their development.

The perfect stage of the fungus, *Mycosphaerella gossypina* (Cke.) Atk., an ascomycetous fungus, has been reported in the United States and China. The perithecia are black, oval, $60-70$ by $65-90\ \mu$ in diameter and are partly immersed in the leaf tissue. The asci measure $40-45$ by $8-10\ \mu$ and contain eight greenish white, elliptical or broad fusoid, bicelled ascospores which measure $15-18$ by $3-4\ \mu$. The ascospores are narrow at the septum and the two cells are often unequal.

Control Measures. The disease is of minor importance. The young plants are affected by the disease only when environmental conditions are unfavourable for plant growth. In mature plants, the damage done to older leaves is usually not very appreciable in this country.

HELMINTHOSPORIUM LEAF SPOT

The disease is of common occurrence in all the cotton growing areas of the world. It has been reported from Puerto Rico (Tucker, 1926), Belgian Congo (Stanner, 1928), Peru (Abbott, 1929; Rada, 1935) and the Philippines (Comus, 1934; Clara, 1935). In India, it occurs sporadically in Dharwar district of Mysore State (Rane and Patel, 1956b).

Symptoms. The disease usually affects the lower leaves but sometimes bracts are also attacked. Numerous light brown, circular spots, measuring 0.5 to $2.5\ \text{mm}$, appear on the affected parts. Later the centres of these spots turn ashy and develop a dark purple border. Finally the ashy centres fall off, leaving holes in the leaves.

Various species of *Gossypium*, viz., *G. arboreum*, *G. barbadense*, *G. purpurascens*, *G. herbaceum* and *G. hirsutum* are susceptible. The disease also affects the tree cotton.

Etiology. The disease is caused by *Helminthosporium gossypii* Tucker.

The conidiophores arise singly or in groups through stomata or epidermal cells of the diseased leaves. They are mostly erect, bulbous at the base, with prominent geniculations, 1-6 septate and measure 37-178 μ . The conidia are borne singly or in clusters of 1-5 at the tips or at different points on the conidiophores in an acropetal succession. They measure 29.7-133.1 μ by 10.6-22.9 μ and are thick-walled, sub-cylindrical or ovate, rarely obclavate, curved, rarely straight, 3-10 septate (mostly 7), wider near the centre and gradually tapering towards the ends.

The fungus perennates on the diseased plant debris, particularly the dead leaves.

ALTERNARIA LEAF SPOT

The disease occurs in almost all the cotton growing countries of the world. In India, it has been reported to be of wide-spread occurrence in the State of Bombay and sometimes assumes serious proportions when humidity is high (Uppal, Patel and Kamat, 1935; Rane and Patel, 1956a).

Symptoms. Small, pale to brown, round or irregular spots measuring 0.5-3 mm. in diameter and with cracked centres appear on the affected leaves of the plant. Later they may coalesce to form larger diseased areas. Sometimes, the leaf veins may also get infected. Ultimately the affected leaves become dry and fall off. In rare cases, the disease may cause cankers on the stem. The infection spreads to the bolls only when the attack is very severe and they may finally fall off.

The disease has been reported in Bombay on tree cotton and various varieties of *G. hirsutum*. Cotton varieties like *G. barbadense*, *G. herbaceum* and *G. arboreum* show a relatively high degree of resistance.

High humidity, intermittent rains and moderate temperatures are congenial for the development of the disease.

Etiology. Four species of *Alternaria* namely *A. tenuis* Nees, *A. gossypium* Thüm., *A. gossypina* (Thüm.) Hopk. and *A. macrospora* Zimm. have been reported to be responsible for the disease in various cotton growing countries of the world (Faulwetter, 1918; Biraghi, 1937; Hopkins, 1931; Jones, 1928; Ling and Yang, 1941). In India, however, the disease is said to be caused by *A. macrospora*.

Alternaria macrospora forms profuse mycelial growth in culture. The conidiophores are dark brown, short or long, 1-8 septate and with solitary conidia at the apex. Usually they are straight or irregularly bent, slightly constricted at the septa and measure 39-132 by 5.8-8.9 μ . The conidia obtained from culture measure on an average 34.4 by 13.3 μ without

beak which itself measures $6.3-73.2 \mu$ (average 16.6μ) in length. They have 3-9 transverse and 0-4 longitudinal septa. They are obclavate or muriform, light to dark brown in colour, with a round base and a tapering septate or non-septate beak. The conidia formed on the leaves are slightly bigger in size and their beaks are also larger than those formed in culture.

The pathogen perennates on the plant debris, particularly the dead leaves.

RUST

The disease though widely distributed, is of minor importance. It has been reported from Ceylon, Java, West Africa, the West Indies, North and South America, New Guinea and the Philippines. In India, it occurs in most of the cotton growing parts (Butler, 1918; Brooks, 1953).

Etiology. The disease is caused by *Phakopsora desmium* (Berk. and Br.) Cumm. Synonyms: *Kuehneola desmium* (Berk. and Br.) Butler; *Cerotelium desmium* (Berk. and Br.) Arth; *Uredo gossypii* Lagerh. The pathogen is restricted mainly to the leaves where it forms the uredo sori. In the United States, the teleuto sori have also been recorded on the leaves. In India, no mature teleuto sori have been observed, though early stages of their development have been reported.

The uredo sori are small and yellowish brown in colour. The uredospores are light yellow, oval or broadly pear-shaped, without any definite stalk, and measure $19-27$ by $16-19 \mu$. The wall is furnished with short but distinct spines. The teleuto sori are cinnamon brown, deep seated in the tissues of the host and break through the epidermis at a late stage. The teleuto-spores are $80-100$ by $10-13 \mu$ in length and are divided by 4-7 septa forming a chain of cells which is laterally united below. Each segment of the spore is irregularly oblong and measures $24-32 \mu$ in length. The walls of the cells are pale golden brown in colour, smooth and thickened at the free end.

The disease mostly affects the sickly leaves which usually fall off. In India, the indigenous varieties are usually not attacked, though the newly introduced foreign types which have not yet adapted themselves to their new environments are affected by the disease.

SOOTY MOULD

The disease has been reported to be of common occurrence in the Punjab and attacks Sea Island, American and Indian Local (*desi*) varieties of cotton (Sawhney, 1927).

The fungus causes great damage to the host plant. It not only injures the cells in immediate contact by killing, crushing and ultimately destroying them, but also damages, indirectly, by lowering the vitality of the plant by sucking out its vital energy through the glands and makes the plant fall a prey to many other diseases and pests. Infection of the bolls also lowers the quality of the lint.

Symptoms. Dark specks are found on the under surface of the leaves and bolls, including their glandular parts. The glands are normally yellowish but gradually they change their colour to various grades of redness and finally black patches of the fungus are seen on their surface.

The infection of the leaf takes place initially in the mid-vein on which the gland develops first. Starting from the gland, the fungus spreads along the vein and subsequently forms a long strip. The disease spreads further to the neighbouring veins where the glands have developed by then. The leaf infection is greatest in Sea Island and least in *desi* glandular varieties whereas the non-glandular *desi* individuals are generally free from it.

Boll infection takes place at the time of maturity, the oldest bolls being the first to be attacked. The glands which are present at the base of the calyx tube are infected easily. Generally, one gland out of three gets infected.

It is believed that the fungus finds a good nutrient medium for growth in the sugary exudation of the glands of Sea Island cotton. It flourishes less on American cotton glands and least on *desi* glandular varieties whereas on the non-glandular *desi* cottons it does not parasitise.

The other parts of the plant, like stem and petiole, can also be infected artificially with the fungus through wounds when the inoculated parts are kept moist for some days.

Etiology. The disease is caused by a species of *Capnodium* which occurs along with *Alternaria* sp. and *Macrosporium* sp. on the leaves and bolls of cotton. Hyphae of the fungus come into close contact with the host only in the region of the glands; outside this region they form a sort of felt over the plant parts. The mycelium forms a jet black patch and consists of branching, septate, anastomosing hyphae which are dark brown in colour. They are composed of mostly uninucleate irregular cells, measuring $10\cdot7$ - $18\cdot5\ \mu$ in length and constricted at the septa. Of the various types of fructification produced, the pycnidia play the chief reproductive role, being abundant both in nature and in culture. Torula spores are quite abundant in nature though less in culture, whereas coniothecia are very rarely found in nature. The pycnidia which are usually found in clusters are of two types. Some are broad and uniformly thick, while others are long, broad at the base, gradually tapering towards the apex and ending in a cup-shaped head. Pycnospores are found in large numbers and are pale brown, thin-walled, ovoid, with one end obtuse and other pointed. They measure 7 - 10 by 4 - $6\ \mu$ in diameter. Perithecium like structures have also been reported both in nature and in culture, containing a few asci with 5 - 8 round ascospores in each ascus.

BACTERIAL AND NEMATODE DISEASES

BACTERIAL BLIGHT

According to Knight (1948), the disease is believed to have originated in India because, "The Indian cottons have been subjected to selection pressure

against bacterial blight for a longer period than the New World cottons." This view, however, is not supported by Patel and Kulkarni (1950) who are of the opinion that the disease was introduced into this country through exotics in the middle of the 19th century because the indigenous cottons are somewhat resistant while the exotics are susceptible to the disease.

The disease was first described by Atkinson in Alabama in 1891 and since that time it has been the subject of reports from workers throughout the cotton growing areas of the world. In India, the disease has been reported from many places in the States of Bombay, Madhya Pradesh, Andhra and Madras.

The disease reduces the photosynthetic activity of the plant by destroying the chlorophyll in the stem and leaves. It may cause shedding or rotting of the bolls. The lint of the bolls may also get stained thereby lowering its market value. Quite often it is instrumental in breaking of the stems by wind. Sometimes the losses caused by this disease are enormous. A loss of 2,40,796 bales of cotton was reported due to the disease in 14 States alone in the United States during 1953 (Leyendecker, Smith, Lett and Lehman, 1954). The disease in the Sudan, even in the years of mild attack, has been reported to reduce nearly one-fourth of the yield. In India, the disease assumes a serious form, particularly in the State of Madras, if it rains in December and January.

Symptoms. The disease usually affects the parenchymatous tissues; very rarely the vascular bundles are penetrated. The following are the four common phases of symptoms that mostly develop.

1. Angular leaf spots on the leaves.
2. Blackarm lesions on the stem.
3. Boll rot and gummosis.
4. Seedling infections.

The common leaf lesions appear first as minute, water-soaked spots on the under surface of the young leaves. Later these spots which are either scattered or localised, increase in diameter up to 5 mm., first turn brown, then black and form angular dead areas with reddish or purplish border bounded by veinlets (Plate Xc). The spots are then visible on the upper surface of the leaf. Often the disease extends along the edges of the veins when it is termed as 'vein blight' or 'black vein'. On the under surface of the leaf bacterial ooze is often seen in the form of crust or scales. Sometimes large dead areas are formed which develop as a result of coalescence of numerous smaller spots. This condition usually leads to the death and shedding of the leaves.

The disease on the stem and petioles appears in the form of elongated greyish to sooty black lesions which under favourable environmental conditions ooze out large quantities of pathogenic bacteria. Quite often severely affected stems show deep cracks and gummosis due to which they are liable to break off by wind. Severe infection may result in the production of the

so called 'blackarm' symptoms when there is girdling and death of the affected organs.

The bolls may be affected at any stage of their development. Basal infection of the flower buds and young bolls may cause these structures to fall off prematurely. The disease appears first as small, round, water-soaked, raised spots. The lesions gradually become irregular in shape, turn brown to deep black in colour and become depressed in the centre. They may remain small or cover the entire boll, penetrating deep into the interior. Saprophytic organisms may attack the infected bolls and cause the boll rot and gummosis. The mature bolls when affected, often open prematurely. The lint in such bolls does not fetch good market price as it gets stained. The pathogen within the boll passes along the fibres and infects the seed externally but the bacterium may even reach the interior of the seed either through the micropyle, the basal cap of the seed or through the punctures made by stainers (Tennyson, 1936; Uppal, 1948).

Very young seedlings may develop lesions on the stem and cotyledons which under favourable environmental conditions may result in their death. The disease first appears on the margins of the ventral side of the cotyledons as small, water-soaked, circular or irregular but not angular spots. It then gradually spreads inwards distorting the shape of the cotyledonous leaves. From the cotyledons the pathogen finds its way to the stem through the petiole and ultimately invades the growing tip, resulting in the death of the seedling.

Etiology. The disease is caused by *Xanthomonas malvacearum* (E. F. Sm.) Dows. Synonyms: *Pseudomonas malvacearum* E. F. Sm.; *Bacterium malvacearum* E. F. Sm.; *Bacillus malvacearum* (E. F. Sm.) Holland; *Phytomonas malvacearum* (E. F. Sm.) Bergey *et al.* The pathogen is a short rod-shaped organism with a single polar flagellum, occurring singly or in pairs and without any involution forms. It is gram negative, not acid fast, capsulated, non-spore former, facultative aerobe and with an average measurement of 1.2 by 0.9μ .

The optimum temperature for the growth of the pathogen is between 31° and 32° C. and minimum and maximum temperatures are 6° and 42° C., respectively. It can retain its viability for three months at 13° C. The thermal death point of the organism is 50° C. In pure cultures, it can withstand freezing as low as -27° C. for one month, but is killed by alternate thawing and freezing. On cotton seeds, it is reported to endure a temperature of 90° C. for five hours in dry air and one hour in moist air. In the leaves, it retains its viability for two months under snow but is killed by alternate thawing and freezing.

The organism is able to liquefy gelatin and can digest starch and casein but not fat. Hydrogen sulphide is produced; nitrates are not reduced; indol not produced; M. R. and V. P. tests negative; little or no growth on Cohn's, no growth in Fermi's and very little or no growth in Uschinsky's solutions. It is tolerant to three per cent. sodium chloride. Loeffler's solidified blood

serum is not liquefied in 10 days. It grows well on several synthetic media containing separately, dextrose, sucrose, maltose, levulose, xylose, raffinose, glycerol, galactose and lactose with the production of acid, but no gas. It does not utilize rhamnose, dulcitol arabinose, mannitol and salicin. Cotton seed oil is not decomposed. Milk is coagulated and peptonised (Elliot, 1951; Burkholder, 1932; Dowson, 1939).

A bacteriophage attacking *Xanthomonas malvacearum* has been isolated in the United States (Roseberg and Barrack, 1955). Preliminary observations suggest that the bacteriophage isolates from Texas and New Mexico may prove useful in the identification of strains of the bacterium occurring throughout the cotton belt.

Recently, Hunter and Blank (1954) have reported a new virulent strain of *Xanthomonas malvacearum* from New Mexico. It has been found to attack resistant Acala seedlings and Acala breeding material with Stoneville 20 types of resistance. The existence of this virulent strain in the United States has threatened the breeding programme based on the Stoneville 20 types of resistance.

The disease has been reported to occur on various species of *Gossypium*, *Thurberia thespesioides*, a wild cotton-like plant in Arizona and New Mexico and *Eriodendron anfractuosum*, a Mexican variety of Koph tree (Heald, 1943). In India, Sundaram (1952) has successfully inoculated *Jatropha curcas* with the pathogen.

Perpetuation and Dissemination. The disease perpetuates mainly through the infected volunteer plants and dry undecomposed plant debris in the field. The pathogen has also been shown to perennate on the surface of the seed and the fibres attached to it. Sometimes, as already stated, the disease can also be carried through the seed internally (Faulwetter, 1917a; Massey, 1930; Hare and King, 1940; Weindling, 1948).

Rain and irrigation water are the two chief disseminating agents for the spread of the disease. Heavy and frequent rains are responsible for its greater spread. In semi-arid regions of the United States, the disease spreads mainly through the irrigation water. The disease has also been reported to be disseminated by dust and wind-blown infected leaves. Insects do not appear to play an important role in the spread of the disease, though they may introduce the bacteria into the bolls (Faulwetter, 1917 a, b ; Rolfs, 1935 ; Brown, 1942 ; King and Brinkerhoff, 1949).

The bacteria enter the host through stomata and wounds. They enter the leaf tissue generally from the lower surface where the stomatal openings are abundantly found.

Predisposing Factors. The primary infection of the disease depends upon soil temperature and moisture prevailing at the time of sowing and a few days after. A temperature of 30° to 40° C. and humidity of 85 per cent. or more are the optimum conditions for the development of the disease. The

presence of moisture is very important for secondary spread of the disease during the first 48 hours of infection. Further development of the disease, however, is dependent on the prevalence of congenial temperature during the incubation period which extends from 3 to 10 days (Stoughton, 1928, 1930, 1931, 1932, 1933). Prevalence of dry and hot weather retards the normal development of the disease (Blank, 1953).

Various cultural practices have a direct bearing on development and prevalence of the disease. Early sowing, delayed thinning, poor tillage and late irrigation increase the incidence of the disease. Deficiency of potash in the soil, too, is said to increase the severity of infection.

Control Measures. The following measures have been found effective in controlling the disease.

Sanitation. Removal and destruction of the volunteer plants from the fields are very essential as they are the chief source of primary infection. Plant debris of the infected undecomposed parts must be ploughed under and the fields irrigated immediately to ensure their quick decomposition.

Cultural Methods. Crop rotation, late sowing, early thinning, good tillage, early irrigation and addition of potash to the soil help to reduce the incidence of the disease.

Seed Treatment. The seed is delinted with concentrated sulphuric acid by immersing for 5 to 15 minutes in earthen jars or wooden tubs coated with pitch. With the removal of fibres, the bacteria adhering to the seed coat are also removed. The seed is then rinsed thoroughly by suspending in water to remove the acid and finally dried before storage. Incidentally it also removes the light weight seed and gives a high grade planting seed (Rolfs, 1935). The United States Bureau of Plant Industry has developed a dry method of delinting cotton seed with hydrochloric acid gas which is considered superior to the sulphuric acid wet method. The subsequent dusting of the delinted seed with mercuric chloride-iodide powder or some of the organic mercurial compounds like 'New Improved Ceresan' gives still better results (Walker, 1950).

Tarr (1956) has developed a 'Mema Short Wet' method for disinfecting the seed in the Sudan. One pound of seed is treated with 50 ml. of concentrated Mema solution (Methoxy ethylmercuriacetate) containing about 0.38 per cent. of murcery. The solution is sprayed over the seed which is then thoroughly mixed for about 10 minutes. In case of heavily infected seed a more concentrated solution containing about 0.77 per cent. of mercury is used.

Development of Resistant Varieties. In the United States all but a few of the current strains of Upland cotton are quite susceptible to the disease. *Gossypium barbadense* (a long lint cotton) is highly susceptible. Stoneville 20, a variety showing a high degree of field resistance, is now being used in the

crossing programme for incorporating its resistance to the commercial types (Walker, 1950; Blank, 1953).

Knight and Clouston (1939, 1941, 1944) and Knight (1948) have done extensive work on the development of resistant varieties in the Sudan. Attempts are being made to improve the long lint Sakel cotton by crossing with Uganda B.31 which is resistant to the disease.

In India, all the exotic varieties of cotton belonging to *G. hirsutum* and *G. barbadense* are susceptible to the disease. The indigenous cottons belonging to *G. arboreum* are affected to a slight degree and those of *G. herbaceum* show a varying degree of susceptibility. The susceptible cotton R. 22 (a Russian strain of *G. herbaceum*) is being improved by crossing with a highly resistant cotton, *G. herbaceum* var. *acerifolium* (Kulkarni and Patel, 1951).

ROOT KNOT

Root knot of cotton is considered to be a serious disease of the crop in the United States and is commonly found in lighter soils of the cotton belt. In India, it has been reported from the Punjab on *G. arboreum* var. *neglectum* f. *bengalensis* (Atkinson, 1892 ; Luthra and Vasudeva, 1939 ; Smith, 1953).

Symptoms. Lack of vigour is the first sign of the disease though ordinarily the affected plants appear to be normal. Severely attacked plants become stunted and their leaves lose the chlorophyll.

In the United States defoliation of the leaves and death of the severely affected plants has also been reported. Diseased plants show knots or galls on the tap and lateral roots (Plate XIa). Sometimes these knots are also found inside the tap root and its tip. They vary greatly in size and shape. Their tissue is soft and usually decays off.

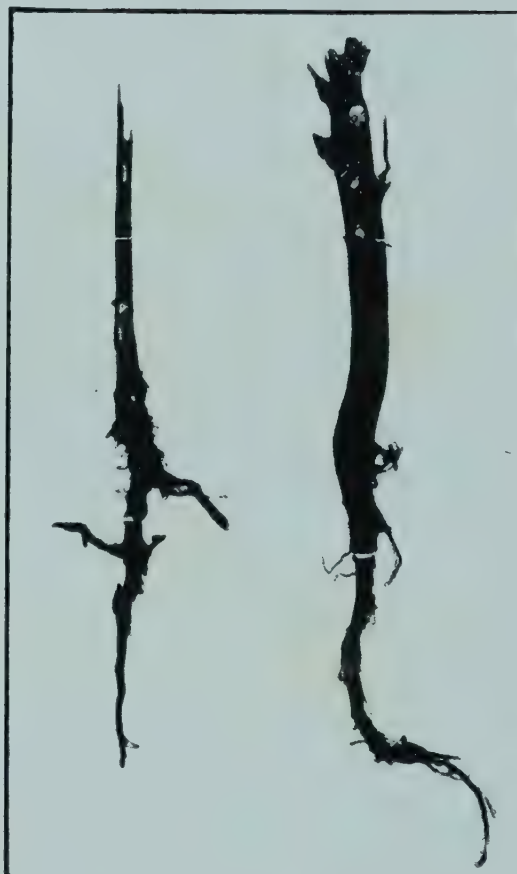
Etiology. The nematode responsible for the disease in India has not been identified.

In the United States, the disease is caused by *Meloidogyne incognita* var. *acrita*. Immature larvae of the nematode attack the soft root tip and push themselves into the tissue. They feed upon the host by puncturing the cell walls with a spear like stylet and sucking up the sap from inside the cells. The affected cells are stimulated to growth and form galls. Within the galls the females swell into pear-shaped bodies and produce a large number of eggs which on hatching infect the neighbouring healthy plants.

Control Measures. In the United States, soil fumigation with Dowfume W.40 (Ethylene dibromide) or D.D. (a mixture of 1, 3 dichloropropane and 1, 2 dichloropropane) has given satisfactory control. Rotation with resistant crops like sorghum, grasses, small grains, corn, peanuts, *Crotalaria*, velvet beans, alfalfa and resistant cowpea has been found to be a valuable cultural practice for the control of the disease. Varietal resistance tests in Alabama (U.S.A.) have shown encouraging results. Anburn 56, a newly released



a. An Infected and Healthy Plant Showing Surface of Wood



c. Cotton Roots Affected with Root Rot in an Advanced Stage



b. Cotton Field Infected with Root Rot

PLATE X



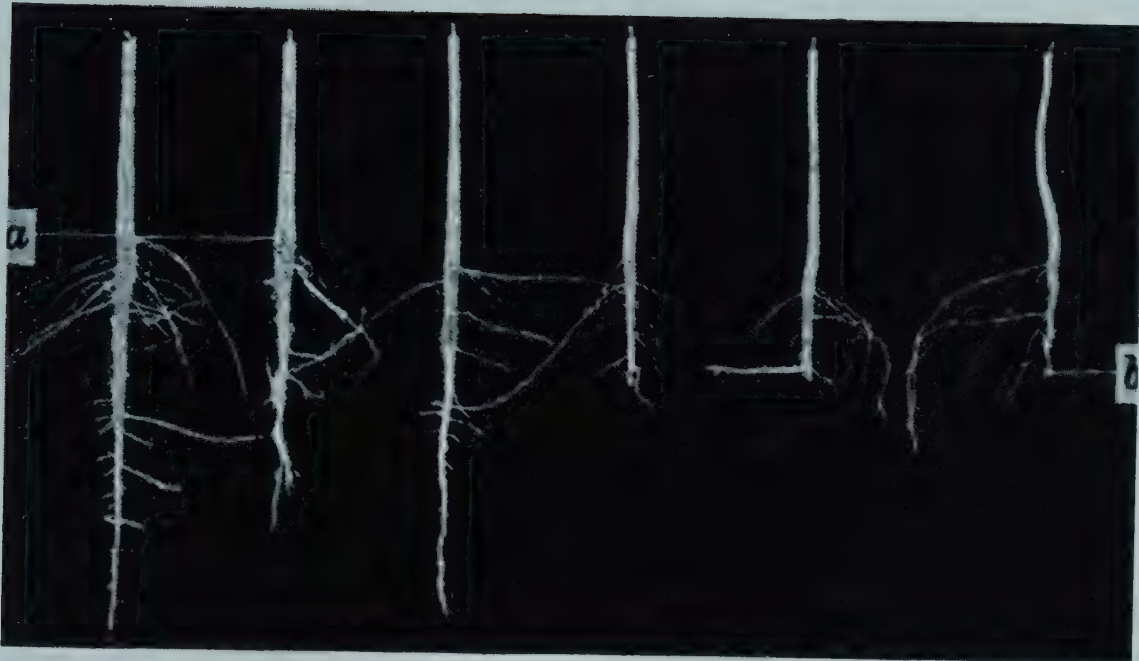
a. Control of Disease by Intercropping with *Phaseolus aconitifolius*



b. Cotton Bolls Affected with Anthracnose



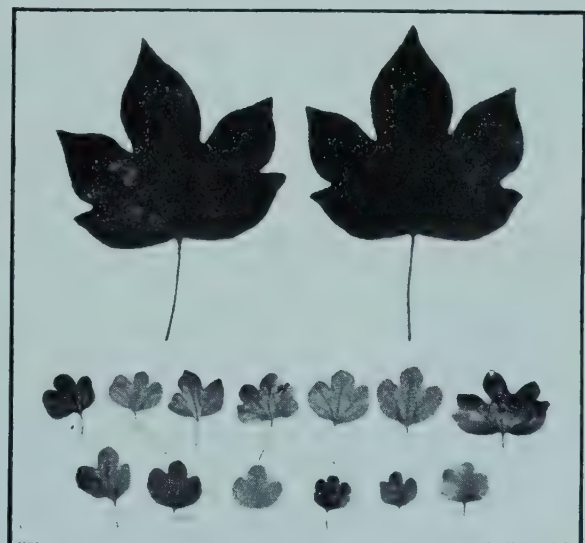
c. Cotton Leaf Affected with Angular Leaf Spot



a. Roots of Cotton Plant Showing Knots Caused by *Meloidogyne incognita* var. *acrita*



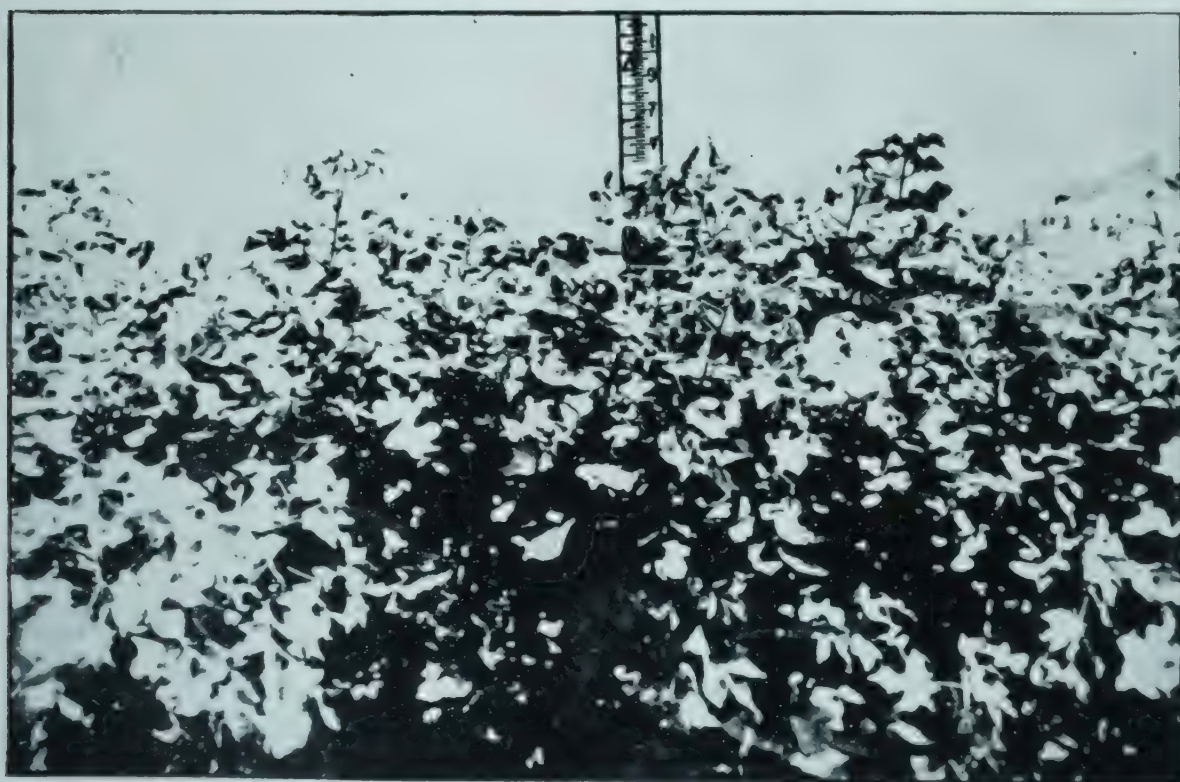
b. Small Leaf Affected Plant and a Heathy Plant



c. Affected Cotton Leaves with Reduced Size and Different Kinds of Lobes and Normal Leaves



a. Field of Cotton Showing Drooping Leaves due to Water Shortage



b. Normal Cotton Crop with Erect and Turgid Leaves

variety, has proved to be far superior in both root knot and the allied *Fusarium* wilt resistance (Smith, 1953, 1954 ; Presley, 1954).

VIRUS DISEASES

SMALL LEAF

The small leaf disease, also known as smalling or stenosis, is prevalent in western India, the Deccan and Madras. Most of the Asiatic cottons are susceptible, *G. herbaceum* types being the worst affected in western India. *Gossypium arboreum* var. *typicum* f. *indica* (Rozi cotton) is particularly susceptible, showing sometimes as high as 35 per cent. infection. In Madras, Mungari cotton, a mixture of *G. herbaceum* and *G. arboreum*, is highly susceptible. The disease has never been reported on the Egyptian cottons. Although the disease has been claimed to be transmitted by grafting to some American cottons, (Uppal, Capoor and Raychaudhuri, 1944), it has never been observed in the American cottons under field conditions (Kottur and Patel, 1920 ; Gokhale, 1936).

Symptoms. The disease starts appearing when the plants are two to three months old. All the aerial parts of the affected plants are stunted. The diseased plants put forth numerous extremely small leaves in cluster and the dormant buds are stimulated to activity resulting in profuse vegetative growth (Plate XIb). The leaves are variously lobed and in majority of cases the lobes are reduced in number (Plate XIc). The flower remains small and the ovaries become abortive. A large number of flower buds and young bolls fall off prematurely. Even bolls which reach maturity are of the size of pea and do not contain any viable seed. The root system of the diseased plant is poorly developed. The growth of the tap root is arrested, giving rise to a number of secondary roots, and such affected plants can be easily pulled out of the ground.

All the branches on the plant may be affected by the disease or only a few among them may exhibit the symptoms. Sometimes the disease affects only the base of the plant resulting in the formation of a clump of short branches which bear small and deformed leaves.

In the affected branches of the diseased plants, there is an accumulation of starch in the roots and vascular bundles of petioles and stems. The diseased leaves also contain a higher percentage of starch as compared to the healthy ones (Likhite and Desai, 1935).

Etiology. The disease is caused by a virus and can be transmitted by grafting but not through seed or sap. The insect vector has not yet been established.

Control Measures. A number of Indo-American hybrids, viz., 134 x Co.2; 170 x Co.2 ; (170 x Co.2)-2(SF) ; 134 x Co.2-M-26(SF) ; 68 x (Exotic 3 x

Acala 8); 68 x 22-(SF); 13C-68 x 22; and Co-tom-23 (SF) tested under insect proof conditions for their reaction to the disease appear to be immune (Vasudeva, 1957).

A somewhat similar disease has been reported by Afzal Mohammad and his associates (1933, 1935) from the Punjab but its casual agent has not been established. The disease is characterised by extreme reduction in the size of internodes, petioles and leaves, large scale shedding of buds and bolls and poor development of the root system. The number of lobes in the diseased leaves is reduced. A few bolls which reach maturity are small and contain only a few viable seeds. The disease may affect all the branches of a plant or only a few among them may exhibit the symptoms. In addition to these symptoms which are also observed in the disease prevalent in Bombay State there is crinckling, discolouration and yellowish mottling of leaves. The stipules are very light in colour and the epicalyx is discoloured but not deformed. The disease in the Punjab is known chiefly to affect the American cottons which is contrary to what has been observed in Bombay State. Further study is, however, necessary to determine whether the disease in the Punjab and Bombay region is caused by the same agent.

NON-PARASITIC DISEASES

TIRAK OR 'BAD OPENING'

The disease is commonly found in the American cottons in the Punjab and Sind, and has also been reported from the Sudan (Dastur, 1944, 1948 1949, 1951). In years of severe outbreaks, heavy losses amounting to 50 per cent. have been recorded in the Punjab. Similar heavy losses have also occurred in Sind (Pakistan).

Symptoms. The disease is characterised by yellowing and reddening of the leaves which appear towards the beginning of the reproductive phase resulting in the early defoliation. There is cracking of the bolls and they contain many partially or fully immature seeds which crack and can be pressed with fingers. The lint in the affected bolls is weak, immature and of poor quality. The weight of the seed is also adversely affected which ultimately results in the reduction of the yield. The disease occurs generally in patches but in years of severe attack may be found in the whole field.

In the Sudan, 'bad opening', as reported by Dastur, results only in the reduction of boll size and in the number of seeds per boll but the seed unlike Indian *tirak* remains hard and sound. The lint, however, remains immature. The average yield of seed cotton even in years of extensive 'bad opening', has been reported to be normal, though the number of seeds per boll is greatly reduced. It has been probably due to higher percentage of flowers setting into bolls as compared to those in the normal years, thus making up for the loss in the boll weight by an increase in the number of bolls per plant.

Etiology. The disease is considered to be due to two adverse soil conditions prevailing in the Punjab and Sind. Soils with high concentration of alkali salts, varying from 0.15 to 0.5 per cent. in the sub-soil at a depth of two or three feet and light sandy soils deficient in nitrogen are responsible for the disease.

In fields with alkaline sub-soils, the cotton plants grow normally until August when it shows signs of water shortage. Later due to non-availability of water from the upper layers and the inability of roots to absorb water from the saline sub-soils, the leaves droop down, dry up and ultimately start shedding by the end of September (Plate XIIa, b). The bolls remain small, open badly and form immature seed and lint.

On light sandy soils, deficient in nitrogen, the plants first grow vigorously until August. Later yellowing and partial reddening of the leaves are observed followed by defoliation. The bolls crack prematurely and the seed and lint remain immature. Thus the symptoms exhibited by the leaves prior to 'bad opening' on the two soil types are different but premature cracking of the bolls with immature seed and lint occurs in both the cases. Sometimes both the adverse types of soil conditions may occur in the same field which greatly aggravate the disease.

During certain years when spells of hot weather prevail in the months of September and October, the disease is intensified owing to further loss of moisture from the crop. Under such abnormal conditions the disease even appears on low salinity soils where normally it does not occur.

The immaturity of seed and lint in badly opened bolls is considered to be due to deficiency of potash in the developing bolls under both sets of soil conditions. In nitrogen-deficient soils, the uptake of potash from the soils is reduced. In areas with saline sub-soils, there is reduction in the uptake of water thereby affecting the uptake of nutrients including potash. The deficiency of potash in the developing bolls leads to the inhibition of protein synthesis. In light sandy soils, the synthesis is further inhibited due to lack of nitrogen as well.

Control Measures. Since the disease occurs because of non-availability of water on areas with saline sub-soils, frequent irrigations have been reported to reduce the incidence of the disease. On light sandy soils, deficient in nitrogen, application of sulphate of ammonia would remedy the cause of the disease. It is, however, not possible to apply these measures for the control of *tirak* under natural field conditions as the patches with saline sub-soils, light sandy soils deficient in nitrogen and normal healthy soils usually occur together in the same field. Remedial measures recommended for one type of soil do not suit to the other type. Application of sulphate of ammonia to the field will not be useful in the patches with saline sub-soils whereas the frequent irrigations, though helpful to this type of soil, will wash down all

the essential available nutrients from the light, sandy, nitrogen deficient and normal healthy patches.

The practical and natural method for the control of the disease, applicable to both types of soils, is to shift the date of sowing to a later period. This will reduce the vegetative growth of the plants, thereby reducing their need of water and nitrogen from the soil and thus the crop would naturally suffer less from *tirak*. Later sowing reduces the yield of the crop which, however, can be made up by close spacing (Vasueva, 1943; Dastur, 1944).

RED LEAF

The disease affects the American cottons in India and is known to be quite serious though no reliable estimates of the losses caused by the disease are available in the country. Butler (1908) first reported the occurrence of the disease. Burt and Haider (1919) from Uttar Pradesh, Kottur (1920) from Dharwar, Prayag (1927) from Khandesh, Milne (1921, 1922) from the Punjab, Sawhney (1932) from the Deccan Hyderabad, Rao and Wad (1936) from central India and Dabral (1938) from Sind (Pakistan) have also reported its occurrence.

Symptoms. The disease appears on the leaves when they become senescent either prematurely or at the end of a life cycle. The chlorophyll in the leaf cells decomposes and probably results in the formation of anthocyanin pigments as soon as the temperature begins to fall below 70° F. Two types of red leaf symptoms have been observed. In one type the green leaves first become pale and yellow and then the red pigment is developed. In this class sometimes the leaves become deep red or scarlet in colour. In the second type the green leaves directly become red without any intervening stage of yellowing. Finally such leaves become bronze or copper coloured. These are the two extreme types of red leaf symptoms but there are intermediate stages which are also commonly met with. In Sind area of Pakistan where these two types of symptoms are very characteristic, it has been noted that the yellow-red type symptoms appear on light sandy soils containing a very high percentage of sand and a low percentage of clay whereas the green-red type occurs on heavy soils containing a low percentage of sand and a high percentage of clay.

The red leaf is a physiological disease and has to be carefully distinguished from reddening of the leaves by jassid injury (Sawhney, 1932).

The disease which has been investigated by Dastur and Singh (1947) and Dastur, Singh and Kaiwar (1952) occurs in various parts of India and Pakistan under different soil and climatic conditions.

Red Leaf in the Punjab: The disease occurs as a result of depletion of nitrogen from the leaves at the fruiting stage. It is common on light sandy soils deficient in nitrogen. The late sown crop is generally less affected by

the disease than the early sown one. The concentration of nitrogen in the leaves of the late sown crop has been found to be higher at each stage of growth than in the leaves of the early sown crop.

The disease has been observed to be more common in southern Sind in Pakistan than in the Punjab even though nitrogen-deficient light sandy soils are widely distributed. This has been attributed to differences in the climatic conditions in these regions. The cotton crop in the Punjab matures slowly because of fall in the night temperatures during October and, therefore, there is no rapid depletion of nitrogen in the leaves. In areas stated above, on the other hand, due to prevalence of higher night temperatures during August to October there is a quick maturation of the crop causing heavy depletion of nitrogen from the leaves. This results in the spreading of the disease to such lands where normally it does not occur.

The development of the disease on nitrogen-deficient light sandy soils can be easily prevented or delayed by application of some nitrogen fertilizer such as ammonium sulphate.

Red Leaf in Central India : The disease appears at the time of boll formation when there is a rapid depletion of food materials from the leaves resulting in their senescence and ultimate reddening. That the disease is not due to any deficiency of nitrogen is clear from the fact that in plots manured with ammonium sulphate it appears two to three weeks earlier than in the controls. The early appearance of the disease in the manured crop is due to its early maturity. By weekly removal of buds and flowers starting from the time of their appearance, it is possible to keep the crop in a vegetative phase and prevent it from early maturity. Leaf reddening in such debudded crop does not appear (except in the case of very old leaves) until the end of the season thereby confirming the finding that red leaf disease in central India is related to maturation of the crop.

Red Leaf in Bombay-Karnatk : The disease appears at the stage of bud formation and declines late in the season. Manuring with ammonium sulphate has no effect on the maturity and appearance of the disease. Weekly removal of buds from the crop also has no effect on the development of the disease. This clearly shows that the cause of the disease in Bombay-Karnatak is not the same as in central India. That these contrary results obtained at the two regions are not due to any varietal difference, is clear from the findings that Indore (central India) cottons when grown at Gadag (Bombay-Karnatak) develop Gadag type of leaf reddening and similarly Gadag cottons when grown at Indore develop Indore type of disease.

In Bombay-Karnatak, east-north-easterly winds which blow during November to January have a dessicating effect on the leaves which results in their reddening. As the easterly winds cease in the later half of January, the progress of the disease declines. No direct experimental evidence in

support of the above conclusion is, however, available. The effect of wind screens on protection of the crop for this purpose, therefore, requires to be investigated.

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I.C.C.C.=Indian Central Cotton Committee.

I.C.G.R.=Indian Cotton Growing Review.

CHAPTER IV

INSECT AND MITE PESTS

Insect pests take a heavy toll of the cotton crop whether it is grown as a rainfed crop or under irrigation. Nangpal (1948) recorded nearly 109 species of insects and mites which infest cotton in India. During the early period of the introduction of American cottons in the Punjab and Sind, such of the varieties as were vulnerable to jassid attack were considered to have no scope for cultivation (Ramiah, *et al.*, 1946). The spotted bollworms (*Earias* spp.) have been observed to cause enormous losses to the cotton crop. Lefroy (1906) writing about the Bombay Locust has remarked that "the damage done by the locusts is probably far less than that done yearly by two pests of cotton, *Earias fabia* and *Earias insulana*." According to Kulkarni and Katgihallimath (1955), the cotton crop in Karnatak (Mysore) is attacked periodically by a large number of insect pests which reduce the yield of the crop considerably.

INSECT PESTS

BOLLWORMS (*Platyedra gossypiella* Saund., *Earias fabia* Stoll, *Earias insulana* Boisd., *Heliothis armigera* Hübn., and *Rabila frontalis* Walk.)

The bollworms are the most important insect pests of cotton in India. Three species are mainly met with—the pink bollworm (*Platyedra gossypiella* Saund.) and two species of spotted bollworms (*Earias fabia* Stoll and *E. insulana* Boisd.). A fourth species, *Heliothis armigera* Hübn. (Syn: *H. obsoleta* F.) well-known as a cotton bollworm in the United States of America, is recorded as a minor pest of cotton in Madras and Mysore (Ayyar, 1932; Maheswariah and Puttarudriah, 1956). *Rabila frontalis* Walk. is another minor pest attacking indigenous perennial cotton and Sea Island cotton in South India.

Damage Caused. One of the earliest references to the damage caused by the cotton bollworms is that of Fletcher and Misra (1919) who estimate the annual loss from them at 20 to 25 million rupees. Prior to 1903, the bollworms were not considered to be very serious pests. In 1905 and 1906, there was a failure of the cotton crop in the Punjab and Sind, respectively, due to bollworm attack. There was another failure of crop in the Punjab in 1911 which was also attributed to bollworms. In South India, the bollworms (specially the pink bollworm) came into prominence with the introduction of Cambodia cotton. The Madras Government promulgated the Pest Act as early as in

1919 for the control of these bollworms (Ramachandra Rao, 1921, 1929). According to Ballard (1923), the damage due to *P. gossypiella* was about 4 per cent. between February and May and 18 per cent. in July, or a little less than half of the total green boll infestation.

Deshpande and Nadkarny (1936) have conducted investigations on the damage caused to the cotton crop in South Gujerat by the spotted bollworms, (*Earias* spp.). The damage is done to the shoots, flowers and bolls. It was estimated that 38 per cent. of the shoots of the main axes of the plants were damaged by bollworm larvae. The larvae also attacked the succulent tops of the side branches and the growing vegetative buds. When the flower buds are formed, the larvae direct their attention to them. They get into the flower buds by making a hole and feed on the anthers and ovaries. Frequently, the buds are abandoned by these larvae after they have done some damage. Even slight boring causes the shedding of the biggest buds. About one-third to one-half of the flower buds are shed due to attack of *Earias* spp.

The bollworm injury to flower buds results in delay in flower formation and opening. The larvae attack flowers and freshly-formed bolls. When a flower is attacked the larvae generally enter the ovary which results in the withering and shedding of the flowers. The bolls are attacked at all stages of growth. Younger bolls are shed when attacked; the bigger bolls are not shed, but *kapas* from them is of inferior market value. Deshpande and Nadkarny (*loc. cit.*) have shown that nearly 87 per cent. of the flowers are shed due to attack of the bollworms. Amongst such of the attacked bolls that yield *kapas*, on an average, about 20 locks per plant are found damaged by the bollworms and the percentage of damaged *kapas* averages about 5 gm. per plant. It is very difficult for a casual observer to appreciate the damage caused by the bollworms to the crop, as the plants look apparently quite healthy.

Richards (1924) stated that in the Punjab, during some years, the losses due to the bollworms were estimated at several million pounds sterling. In Uttar Pradesh he (1937) recognised the importance of the bollworm attack in the early twenties. His investigations on the economic status of the pink bollworm are interesting and instructive. Cage studies conducted in 1925 showed that the yield of clean cotton was 4.04 maunds per acre in uninfested cages as compared to 2.0 maunds in the infested cages. In 1926, it was 10.02 and 4.3 maunds per acre in the infested cages. In 1930, detailed field observations were made in Bijnor and Aligarh districts. The yield figures showed that the treated plots gave an average yield of 12 maunds 27 seers per acre as against 8 maunds 27 seers per acre of control plots, in Bijnor district. The figures for Aligarh district were 13 maunds 4 seers and 6 maunds 21 seers, respectively. At the joint meeting of the Agricultural, Zoological, Botanical and Medical Research Sections of the Indian Science Congress held at Banaras in 1925, he said that in his State, the loss of the cotton crop

from the pink bollworm alone appeared to be over 25 per cent. Clouston (1927) reports that in the United Provinces, this bollworm causes a loss of 20-40 per cent. of the cotton crop.

Patel (1949) has pointed out that in Baroda, which is an important cotton growing area, the spotted bollworm (*Earias fabia*) is mainly responsible for damage to the cotton crop and low yields.

Nadkarny's (1951) observations over a period of seven years in the Marathwada tract of Bombay State have shown:

1. The damage done to ripe cotton by the pink bollworm, *Platyedra gossypiella*, and spotted bollworm, *Earias fabia*, varies from year to year. In seasons when the crop is late, the damage is greater. If the pink bollworm appears early due to favourable weather conditions the damage is much more extensive.
2. It is the pink bollworm which is responsible for most of the damage to ripe cotton, although the damage from spotted bollworm attack is not negligible. The spotted bollworm seems to be responsible to a higher degree than the pink bollworm for rendering the boll completely useless, as some fungus subsequently attacks the infested bolls.
3. Cotton brought to the market is only a part of the total cotton produced by the plant. Some of it is left on the plant as it is unpickable. The actual damage is thus greater than that one finds in the marketted cotton.

In normal years the loss of crop is 10 to 17 per cent. by weight, the loss in quality being additional. But in bad years, this loss reaches 25 to 35 per cent. The reduction in the weight of clean *kapas* is found to be caused by different factors. The bolls attacked by bollworm open three to four days earlier than the healthy ones. Early opening of the bolls has an adverse effect on the seed weight, lint weight and ginning percentage of the sound locks. The attacked bolls give generally stained and weaker cotton fibres. Apart from the loss of lint there is a definite loss of seeds also. A number of seeds are hollowed out by bollworms. The estimated loss of seed is about 7 to 20 per cent.

Platyedra gossypiella Saund.

The pink bollworm is distributed all over the cotton growing areas. The caterpillar is distinguished from the *Earias* spp. by its uniform pale pink colour. The adult insect is a dark brown moth with a wing expanse of not more than 0.6". As stated by Marlatt (1918) it is probably an indigenous insect as it was first described from Bombay early in the 19th century. Its spread to Egypt, has been traced to its introduction from India in ginned cotton, used as a packing material. In such places where there are no cotton plants during some part of the year, the caterpillars tide over the unfavourable season inside the empty cotton seed, in which they are well protected and remain

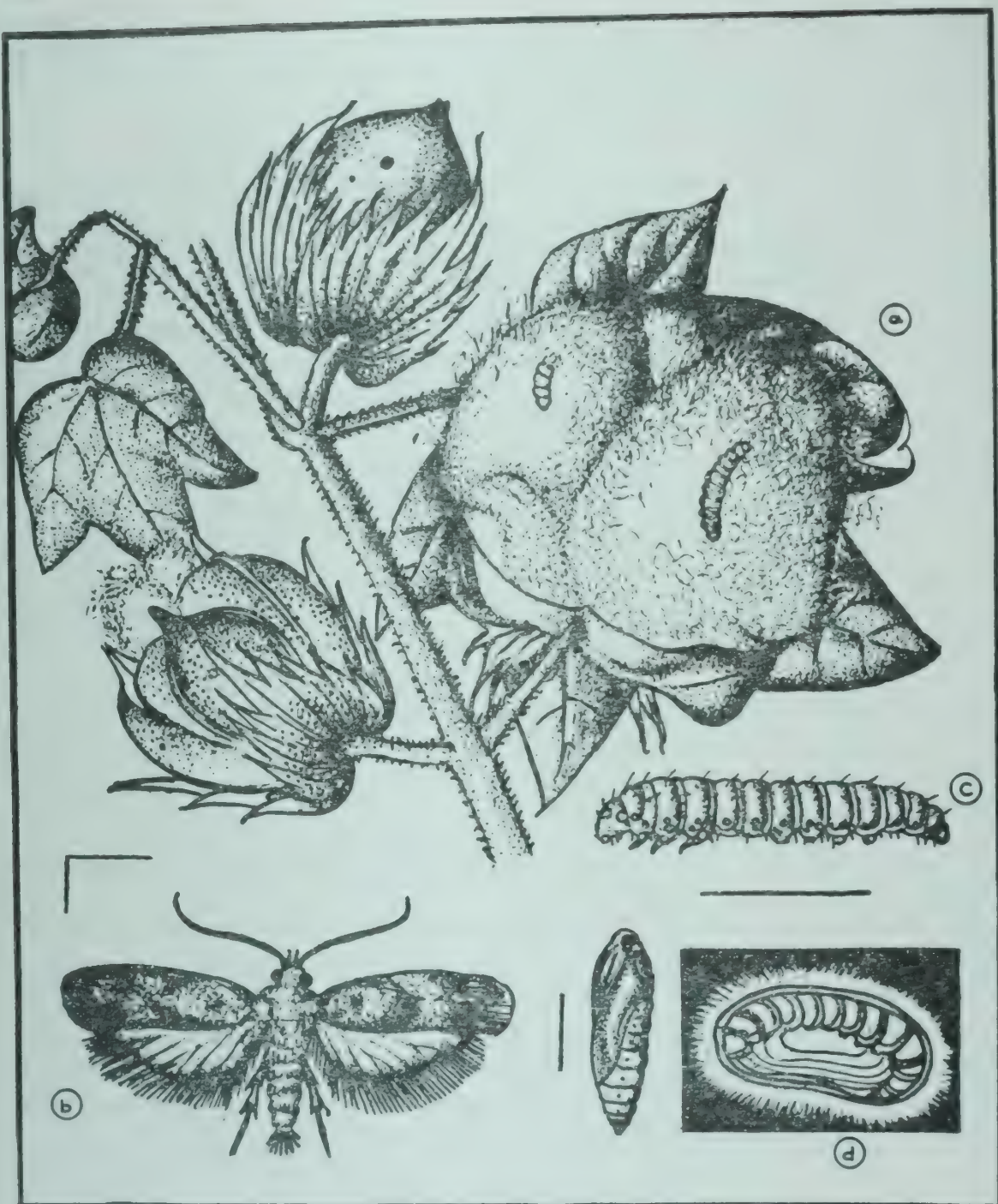


Fig. 35. Pink Bollworm (*Platyedra gossypiella*, Saund.) a. Infested Bolls. b, c and d. Moth, Caterpillar and Pupa along with a section of seed showing hibernating caterpillar

alive for many months. In rare instances survival of as much as eighteen months at a stretch and subsequent emergence as moths has been recorded. The insect is highly adaptable to different climatic conditions as is evident from its wide distribution all over the country.

In spite of its being an indigenous and important pest of cotton crop, enough research has not been done on it, with the exception of perhaps Richards' (1937) investigations.

Life History. *Platyedra gossypiella* is known to hibernate as a full-fed caterpillar during the cold weather. In Uttar Pradesh, Richards (1937) states that the survival of the pest from one season to the other takes place entirely from the hibernating of caterpillars inside the hollowed out seeds of cotton. Whenever the individual cotton seed is not large enough to accommodate the resting larva, then it attaches two or more emptied seeds, lining the cavity with silk. It is generally difficult from a cursory examination to distinguish the sound seed from the seed carrying the hibernating caterpillar. As against the observations of Richards (*loc. cit.*) that the larva hibernates in the cotton seed, Ayyar (1932) emphatically remarks that under South Indian conditions it is not so. In Marathwada tract of Bombay State, Nadkarny (1951) observed that the seed is not as important a source of carry-over for *P. gossypiella* as the soil.

In Uttar Pradesh, Richards (1937) noted that the *hibernacula* containing live caterpillars are sown with the sound seed. The caterpillar soon after sowing makes its way out from the hibernaculum and works upwards through the soil. Having carried the tunnel up to the surface it goes down again to pupate. Thus the moth on emergence has no difficulty in coming out through the soil.

The moths emerging from the resting caterpillars are relatively long-lived. Females remain alive for 56 days and males for 20 days. The moths are not active during day time and remain concealed under leaves or lumps of soil. If disturbed they immediately seek fresh shelter. They become active towards dusk and are occasionally attracted to light. In view of the greater period of longevity the female moth is able to await the development of fruiting bodies on the young cotton plants. About the time the plants are ready to produce flower buds, the female moth lays small, flattish, white eggs mostly on the tender parts of the cotton plant. The maximum number of eggs laid per female moth is estimated to be 220 in Uttar Pradesh, 456 in the Punjab and 375 in Bombay. The average is about 125. The eggs are laid singly, usually on the undersides of young leaves, stems of young shoots, young flower buds, bracts of flowers and the stalks of cotton bolls. The female moth continues to lay eggs in the laboratory over a period of 23 days whereas in the cotton fields the eggs are laid in a few days only when flower buds are developing. This accounts for the periodicity in subsequent generations

which is often a marked feature of the pink bollworm incidence in the crop.

The development of the caterpillar inside the egg takes 4-5 days in the monsoon in Uttar Pradesh, 8-16 days in the Punjab and 9-25 days in Bombay. The young caterpillar is minute, white in colour, with a small dark head. It wanders searching for buds or bolls, sometimes feeding to some extent on the leaf tissue and occasionally entering a young shoot, the pith of which may be bored for about $\frac{1}{2}$ to $\frac{3}{4}$ inch, but the insect cannot be reared on shoots. The first brood during the cotton season develops mainly on buds and flowers. The caterpillar feeds upon the developing anthers and style, and occasionally on the ovary. At the exhaustion of food material they move from one bud to another. Small buds thus attacked are shed. Larger buds develop, but their *kapas* is of low quality. Open flowers are also attacked, the caterpillar feeding down the column into the ovary. Attacked flowers are seldom fertilised, the young bolls being shed a few days after the falling of the corolla. The larger bolls mostly remain adhering to the plant. The full-fed caterpillars leave the fruiting bodies before pupation, most of them entering the soil to pupate, but occasionally a cocoon is spun on a bract or against fallen leaves, or inside a fallen flower. The pupal stage lasts 6-17 days in the Punjab, 7-15 days in Madras and 7-20 days in Uttar Pradesh and Bombay.

The caterpillar undergoes three moults before pupation. It assumes the characteristic pink colour in its third instar; this, however, depends upon the nature of food. The caterpillars found in flowers are often dirty purple in colour until the final instar.

Under favourable conditions during the monsoon season the complete life cycle occupies between 23 and 31 days. The average duration of each stage in Uttar Pradesh is as follows:

Incubation period	..	4	days
1st instar	..	2	„
2nd instar	..	3	„
3rd instar	..	3	„
Pupal period	..	12	„

Copulation usually takes place at night, soon after emergence, and egg-laying commences from the third day onwards. Figure 35 depicts important stages of the pest.

In Uttar Pradesh four broods are generally observed during the *kharif* season, if the monsoon rains set in early. A fifth generation is also observed in late November or early December. Under favourable weather conditions, multiplication may be very rapid. The weather conditions favourable for the outbreak of *P. gossypiella* in Uttar Pradesh are: warm but not excessively hot weather, cloudiness, and frequent but not excessive rain. Long spells of dry hot weather are associated with lesser pink bollworm incidence in the field and lesser damage to the crop.

In the undivided Punjab, Khan (1938) investigated in detail the incidence of *P. gossypiella* in relation to climate. He observed that, in general, where the attack is high, the climate is mild and humid, and thus favourable for the procreation of the pest. While in places where the incidence is low, the climate is hot and dry and unfavourable for the multiplication of the pest. Taking rainfall as an index of the climatic complex, the Punjab was divided into four zones designated as: (i) zone of 'normal outbreaks'; (ii) zone of 'occasional outbreaks'; (iii) zone of 'possible outbreaks'; and (iv) zone of 'no outbreaks'.

Two types of generations are met with: (i) the short cycle generation; and (ii) the long cycle generation. There is generally a periodicity in the generations which tends to become masked late in the season owing to overlapping of broods. It thus becomes necessary to make frequent counts of the bollworm population in the field to arrive at any approximate estimate of the total population, as counts coinciding with pupation of the majority of the caterpillars would indicate either a very low infection or none at all. This may possibly account for the failure of earlier workers to recognise the importance of this pest.

If developing bolls are still available on the plant, the short cycle habit may persist even during cold weather but the life cycle is greatly lengthened. Thus the incubation period will be about 23 days instead of the normal 4 days, and the whole life cycle will occupy about $3\frac{1}{2}$ months. The proportion of the insects which continue to develop without true hibernation is, however, very small. With the fall in temperature and humidity at the close of the monsoon the hibernating habit is induced and the majority of the caterpillars which become full-fed after the middle of November either prepare *hibernacula* in the seeds or make their way into the soil and remain quiescent for 6 or 7 months until the break of the succeeding monsoon. This generation, in which there is a more or less prolonged diapause in the full-fed caterpillar is known as the long cycle generation. Williams (1934) states that the occurrence of long cycle larvae of *P. gossypiella* which remain in a resting stage between the double seeds for 6-18 months, appears to depend largely on climatic conditions and are confined to drier areas. The resting stage occurs in Egypt and apparently in the Punjab and during the hot weather in the Sudan, but is non-existent in the West Indies and practically so in Coimbatore.

Ayyar (1932) states that in South India, *P. gossypiella* does not hibernate inside the cotton seeds and has no alternate host plant.

Sawhney and Nadkarny's (1942) investigations in the Marathwada (Bombay State) have shown that very few larvae of *P. gossypiella* hibernate in the seed as has been observed in Uttar Pradesh, the Punjab and Egypt. Most of the hibernating larvae exist in cocoons occurring either amongst the fibres or *kapas* or in the cracks of the black cotton soil, after the end of rainy season.

Investigations made by Ballard (1921) show that it is doubtful if a long cycle type of larva exists in South India, which is probably due to the absence of cold weather.

Nangpal (1948) states that, in Madras, *P. gossypiella* keeps on breeding throughout the year and that no long cycle generations have been observed.

In Berar, it has been found by Dutt, *et al.* (1943) that both long and short cycle larvae exist, the larval stages lasting 20-41 days and 8-9 months, respectively. Short cycle larvae were found to be present on cotton plants until the end of April after which green bolls were no longer available.

Alternate Host Plants. Alternate host plants are very important from the point of view of effective control of the pink bollworm. Ayyar (1932) emphatically states that no alternate host of the pink bollworm exists in South India. In Uttar Pradesh, Richards (1937) records that under artificial infestation *Abelmoschos esculentus* is most important showing up to 21 per cent. attack in the pods followed by *Hibiscus cannabinus* with 1 per cent. attack, and *Hibiscus sabdariffa* and hollyhock. Of the wild host plants, *Abutilon indicum* carries the maximum attack of 2 per cent. in the green pods. But, according to him, none of the above alternate host plants are of importance in the perpetuation of *P. gossypiella* as they are not dormant (in case of wild hosts) or commonly cultivated (in case of cultivated plants) during the hot weather.

Nangpal (1948) lists the following as alternate host plants of *P. gossypiella*:

Common name	Botanical name
Umdii	Not known
Deccan hemp	<i>Hibiscus cannabinus</i>
Kanghi	<i>Abutilon indicum</i>
Gulkhera	<i>Althea rosea</i>
Jangli ambadi	<i>Hibiscus panduriformis</i>
Musk mallow	<i>Hibiscus abelmoschos</i>
—	<i>Hibiscus rugosus</i>
Portia	<i>Thespesia populnea</i>

Nadkarny (1951) mentions Lady finger (*Abelmoschos esculentus*) and tree cotton (*dev-kapas*) as alternate hosts of *P. gossypiella* in Marathwada.

Natural Enemies. Ayyar (1928) reported *Chelonus* spp. (Braconidae) as parasitic on the pink bollworm in South India. Richards (1937) mentions *Bracon kitchneri* Willcocks, *Microbracon lefroyi* D. & G. *Apanteles* sp., and an unidentified Chalcid a Braconid and a Bethyloid, as parasitic on *P. gossypiella* in Uttar Pradesh.

Cherian and Kylasam (1941) made preliminary observations on three parasites, namely, *Goniozus* n. sp., *Apanteles pectinophorae** and *Microbracon gelechidiphagus* Ram. Ayyar.

* This species has apparently not been described by the authors so far.

Nangpal (1948) gives the following list of natural enemies (Table 41).

TABLE 41. LIST OF NATURAL ENEMIES OF *Platyedra gossypiella*

Family	Species	Host stage attacked
Anthocoridae	<i>Triphleps pectinophorae</i>	Egg
Braconidae	<i>Microbracon lefroyi</i> D. & G.	Larva
	<i>M. hebetor</i> Say.	Larva
	<i>M. gelechidiphagus</i> Ram. Ayyar	Larva
	<i>Bracon kitchneri</i> Willcocks	Larva
	<i>Chelonus</i> sp.	Larva
	<i>Apanteles pectinophorae</i>	Larva
	<i>Apanteles</i> sp.	Larva
	<i>Rhogas aligharensi</i> Qadri	Larva
Elasmidae	<i>Elasmus platyedrae</i> Ferr.	Larva
	<i>Elasmus johnstoni</i> Ferr.	Larva
Bethylidae	<i>Goniozus</i> sp.	Larva
	A species of Bethylid	Larva
Chalcididae	A species of Chalcid	Pupa
Eulophidae	A species of Eulophid	Pupa
Acarina	<i>Pediculoides ventricosus</i> (Newport)	Larva

Thompson (1946) has in addition mentioned *Elasmus* sp. and *Microbracon greeni* Ashm., and Muesebeck (1956) has described *Petalodes gossypiella*, a new species from India.

The female of *Goniozus* sp. selects fourth and fifth instar caterpillars for egg-laying. She usually approaches the host from behind, seizes the host by the nape on the upper surface with her mandibles and curves round its abdomen. Series of stings are given in quick succession in the neighbourhood of the first thoracic segment on the ventral side. Six to thirteen eggs are laid at a time by the parasite on the intersegmental rings of the abdominal segments. The eggs are translucent, white in colour and are difficult to make out when freshly laid. The eggs hatch in 36-72 hours and the parasite grubs start feeding immediately from the same place and never leave their positions. The life cycle is completed in about 12 days (Cherian and Kylasam, 1941). In nature, as high as 49 per cent. parasitization has been observed.

Apanteles pectinophorae is an internal parasite of *P. gossypiella* and appears to be an exclusive parasite of it. Only a single parasite comes out of the body of the host. It is not possible to say from external symptoms whether a particular caterpillar is parasitised or not. The parasite is found in the fields from December to June, though not in appreciable numbers.

Microbracon gelechidiphagus occurs as an exclusive parasite of the advanced caterpillar stages of the pink bollworm, infesting the medium and large-sized bolls of cotton. The incidence of field parasitisation rarely exceeds 22.5 per cent. Furthermore, the parasite appears very late in the season when the host population is generally high.

Work done so far has revealed that there are no satisfactory parasites for effectively controlling *P. gossypiella* Saund.

Control Measures. Satisfactory control of the cotton bollworms is really a pressing problem in India, especially with the existence of short cycle and long cycle strains in *P. gossypiella*.

Varietal resistance studies have shown that it is not possible to evolve a cotton variety absolutely resistant to bollworms. Employment of light and scent traps for the trapping of adult moths have also not been successful. Until further investigations are made and effective parasites imported, chemicals may be used for the control of the pests.

In Madras State, for the satisfactory control of both the pink and spotted bollworms, a legislative enactment called the 'Cotton Pests Act' was enforced as early as in 1919 (Ramchandra Rao, 1921). The object of the Pest Act as enforced against Cambodia cotton, which is more susceptible to attack by the pink bollworm and other pests, is to enforce the removal of cotton stalks by first of August every year. The idea is to create as long an interval as possible between two cotton crops so that the pest may be starved out and considerably reduced in number. Recent communication from the Madras Agricultural Entomologist states that the continued enforcement of the Pest Act has done considerable good.

In Uttar Pradesh the problem is the prevention of carry-over of the pest in the harvested cotton, notably the seed. Fumigation of the seed is very effective in killing the larva. As early as 1927, Clouston reported that infestation of the pink bollworm can be prevented by heating the cotton seed to a temperature of 140°F. for a few minutes before sowing. Experiments conducted later by Richards (1937) showed that the heat treatment of the seed cotton is very effective in destroying the hibernating larvae. It has been found that heating the seed to the maximum permissible temperature of 144°F. kills the larvae and does not affect the viability of the seeds. The Simon Cotton Seed Heater provided with a specially sensitive thermostatic control has been found to be effective for the heat treatment and also in regulating the temperatures. Sun treatment of the seed during the months of April and May is equally effective for treatment of small stocks as the temperature of the seed is raised to 125°F. which is considered to be the lower lethal point.

Fumigation of cotton seed with Methyl bromide at 1 lb. per 1000 c. ft. space with 24-hour exposure resulted in complete mortality of the larvae. Srivastava (1959) has found fumigation of cotton seed with Methyl bromide at 2 cc. per maund, exposing the seed to fumes for 10-12 hours or drying the seed in thin layers in hot sun to be effective.

The fatal temperatures for the pink bollworm have been worked out in detail by Pruthi and Ahmad (1941). Naked larvae and larvae enclosed in seeds of an American variety of cotton or in the compact seeds of a native

variety, were exposed to various high temperatures. At 158°F. the time required to effect 100 per cent. mortality was 1-3, 3-5 and about 7 minutes, respectively, and it was found that at all temperatures mortality was more easily obtained in the American seed than in the native seed. Pruthi (1942) states that larvae of the pink bollworm in cotton seeds resist higher temperatures under dry conditions than under humid ones. Exposures of the seeds for 24 hours to 113°F. kills all larvae if the saturation deficiency of the air is 3-14 mm., but not if it is 32 mm.

The viability of cotton seeds was not materially affected by exposure for 20 minutes to 149°F. or for 7 minutes to 176°F. Nangpal (1937) has found, in Marathwada (Bombay State), that *P. gossypiella* is carried over through soil. Results of a clean-up scheme for cotton bollworms in Marathwada areas have been given by Sawhney and Nadkarny (1942).

Kulkarni, *et al.* (1958) report that in Khandesh the pest reduces the yield to the extent of 25 per cent. besides spoiling the quality of the lint. In their opinion, the cultivation of summer and *kharif bhendi* and ratoon crops encourage the multiplication of the spotted bollworms. Late uprooting of cotton stalks causes early appearance of the pink bollworms.

Sharma and Mohindra (1948) stated that the effective method of controlling the pink bollworm in Sind was to destroy the host plants during the off-season. The Punjab *kudali* was found to be more suitable for removing cotton sticks than the plant puller. The clean-up campaigns were carried out in the districts of Tharparker and Hyderabad over an area of 87,000 to over one lakh acres under cotton cultivation. Each campaign lasted for a period of three months starting from December and ending by February. Besides cotton sticks, *Abutilon* (Patiteer weed), the chief host plant, *bhendi* and hollyhock were also removed. In the treated area the pest was almost absent from May to July each year. From August to November the incidence of the pest on buds and bolls in the treated areas was three to four times less in 1942 and two to three times less in 1943, than noticed in the cleaned area. Nadkarny (1951) has detailed the following recommendations for the control of the pink bollworm, which are mostly preventive.

1. Prevention of the carry-over of the short cycle pink bollworm through the stand over cotton plants and alternate host plants.
2. Eliminating or reducing the possibility of the long cycle pink bollworm, going on from season to season through soil or *kapas*.
3. The growing of early-maturing varieties to escape the severe infestation by the pest.
4. Non-cultivation of American varieties which are more susceptible to the pink bollworm attack, if it is possible to grow equally good *desi* varieties in the tract.
5. Non-cultivation of both *kharif* and *rabi* cotton in the same tract.
6. Final pickings in normal years to be done before the end of December.

7. Thorough grazing of the plants after final picking is over and harrowing of the field thereafter.
8. Ginning of seed cotton before the end of April.

Insecticidal trials with chlorinated hydrocarbon compounds have been initiated only in recent years. Field trials with DDT and BHC have not given convincing results in Madras. Gupta and Joshi (1955) recommended dusting with 5 per cent. BHC at 25 lb. per acre or spraying with endrin 20 per cent. emulsifiable concentrated at 1-1½ lb. per acre.

The recommendations in vogue in Mysore against the pink bollworm are: (i) collection and destruction of infested bolls; (ii) dusting of 5 per cent. BHC on developing bolls; and (iii) selection of healthy seed for planting (Maheswariah and Puttarudriah, 1956). Chowdhury and Majid (1954) advocate the following measures of control in Assam: (a) fumigation of seed; (b) selection of healthy seeds before planting; (c) plucking-off and destroying the first crop of affected bolls; and (d) spraying with 50 per cent. water dispersible DDT or BHC or dusting with 5 per cent. BHC dust.

Earias fabia Stoll. and *Earias insulana* Boisd.

At the Second Entomological Meeting held at Pusa in 1917, it was mentioned that *E. insulana* was more common in the West Punjab and that both species cause immense loss to the cotton crop in India, but it is in the Punjab that the damage is more pronounced. According to Pearson (1958) damage due to *Earias* spp. is more serious in India than in Africa and he has given probable reasons for this in the light of the evidence from Africa (Fig. 36).

Earias fabia occurs in abundance in regions with comparatively greater rainfall while *E. insulana* is found in drier regions. Both species are met with in places where the climatic conditions are intermediate. Ahmed and Ullah (1939) mention that *E. fabia* is serious in areas having moderate climate, e.g., Madhya Pradesh, Bombay, Mysore and Madras. On the other hand, in North-West India (pre-partition) with extremes of climatic conditions, *E. insulana* was the more serious pest. In Delhi, with a climate somewhat intermediate between those of the areas mentioned above, both the species of *Earias* are common, though *insulana* continues to preponderate. Khan (1944) studied the effect of rainfall and temperature on the relative abundance of the two species in the Punjab.

Life History. *Earias* spp. moths emerge generally after sunset. Copulation takes place two or three days after emergence in the early hours of the morning but, in some cases, moths copulate on the night of their emergence from pupal cocoons. Mating period usually lasts from one to three hours.

Oviposition takes place on the first night after copulation, but some of the moths commence oviposition as late as the fifth day after mating. The moths

in captivity live from 8-22 days, the maximum longevity noted being 34 days.

Egg-laying capacity of the moths differs considerably. Lefroy (1906) mentions 60 as the normal number of eggs laid by a single female moth. Deshpande and Nadkarny (1936) observed that a moth could lay as many as 432 eggs on an average with a maximum of 697. Most of the oviposition occurs during the first seven days of the period of egg-laying.

Egg-laying capacity of the moth is not constant throughout the year. It declines considerably during the cold months of December and January. The food plant on which *Earias* larvae are reared has a great influence on the capacity of the moths for oviposition. It has been found that moths emerging from the larvae reared on pods of *Abelmoschos esculentus* lay more eggs than the moths emerging from larvae fed on tender shoots, flower buds and bolls of cotton. Eggs are laid singly and the female moths prefer hairy objects to non-hairy ones. In the cotton fields hairy portions of the plant like tender shoots, stalks of flower buds and bolls, and the petioles are selected for oviposition.

In South Gujerat the incubation period lasts for 4 days, except in cold weather months when it varies from 5-7 days. Fletcher and Misra (1919) stated that the eggs of *Earias* spp. take about 3 days to hatch, during April-September, in Pusa. Ahmed and Ullah (1939) have shown that in the Punjab *E. insulana* eggs take 2-4 days to hatch during summer and 9 days in winter. The eggs are spherical, bluish green in colour with parallel longitudinal ridges which project upwards. The newly hatched caterpillar is brownish white in colour with a dark head and prothoracic shield and measures about 1.3 mm. The caterpillars, soon after emergence, do not begin to feed directly on the nearest available food, but wander about for a few hours before boring in. The rest of the feeding is done in concealment either in tender shoots, flower buds or bolls. The caterpillars feed for a short period on one part of the plant and then migrate to another. It is very common to find a large number of flower buds and bolls which have been left by the larvae after destroying only small portions of these parts.

In nature, the larval period varies considerably at different places and at the same place at different times of the year. At Pusa, Fletcher and Misra (1919) report that the length of larval period lasts from 9-20 days. At Surat, Deshpande and Nadkarny (1936) record that during winter months it varies from 14-16 days and 10-12 days during the remaining period of the year. In the Punjab, larval period of *E. insulana* lasts from 10-16 days in summer and 50-60 days in winter.

Deshpande and Nadkarny (1936) state that the kind of food available to the larvae has some influence in determining the length of larval period. The larval period is found to be slightly shorter when the larvae are reared on *Abelmoschos esculentus* than on flower buds and tender vegetative

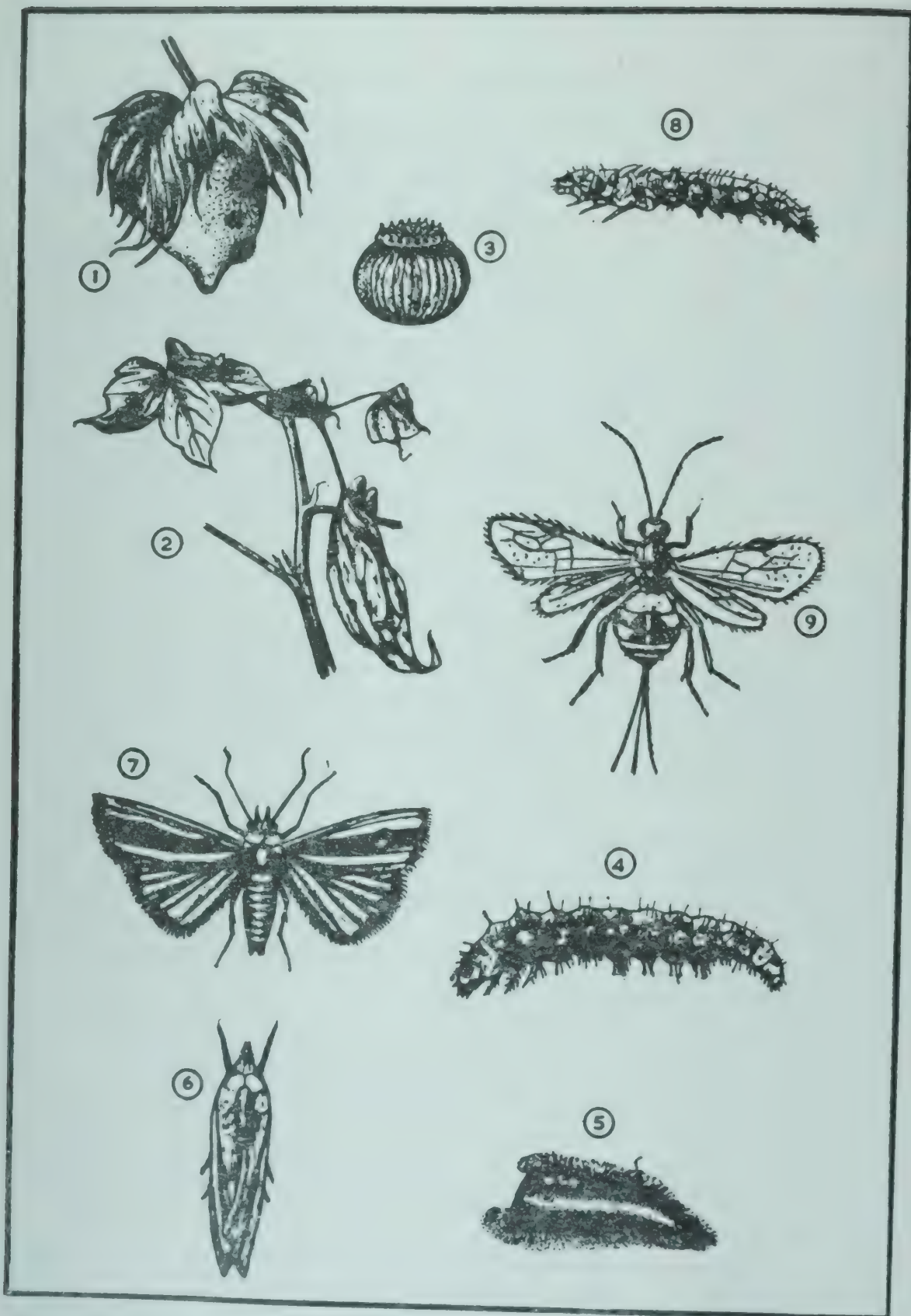


Fig. 36. Spotted Bollworm (*Earias insulana*, and *E. fabia*). 1 and 2. Attacked Boll and Shoot. 3 to 5. Egg, Larva and Pupa. 6 and 7. Moths. 8. Parasitised Worm. 9. Parasite (*Microbracon*)

shoots of cotton.

In Surat it has been observed that the caterpillars when full-fed descend from the plant and go to the soil for pupation. Ahmed and Ullah (1939) state that *E. fabia* pupates outside the plant tissue, usually in dry buds, on leaves and bracts, or inside soil crevices. Nangpal (1948) mentions that mature larvae pupate on the plant during August-October, and on the ground during November-December in the Punjab and Sind, but in Uttar Pradesh, Bombay and Madras they generally pupate in shed materials on the soil. In normal field conditions the pupae can be traced to a depth of about 10-12 inches of the soil. The pupae are purplish brown in colour with a distinct median carina on the thorax, the fifth abdominal segment having a number of prominent points and the last segment being furnished with three teeth-like prominences. The pupae are enclosed in tough silken cocoons of dirty white to light brown colour. In case where the pupae are found in finely pulverized surface soil, small particles of soil are attached all over the cocoon.

At Surat the pupal period varies from 8-14 days, the maximum period being noticed during the cold weather months. In Marathwada it varies from 6-23 days and in South India from 8-10 days.

The entire life cycle occupies 22-35 days in Surat, 18-46 days in Marathwada and about 25 days in South India. Both species pass through about 7-8 generations in Marathwada.

Seasonal history studies at Surat indicate that *Earias* spp. begin to increase rapidly in the cotton fields soon after the close of the south-west monsoon. They feed on the shoots, flower buds and bolls as they begin to appear, in succession. They begin to decline in number by the end of December, partly owing to the cold weather and partly due to parasite activity.

According to Cherman and Kylasam (1947), in Madras State, where cotton is grown in September or October, attack first becomes visible in November, the affected top-shoots showing signs of withering. Larval populations were highest from the middle of May to July and from the middle of December until early January.

Mention should be made of the work of Khan and Ghani (1944) in the Punjab in crossing different species of *Earias*, namely, *fabia*, *insulana* and *cupreoviridis*. It may be mentioned that a certain amount of occasional inter-copulation takes place between the species in nature and under caged condition. The moths of different species copulate more frequently.

Natural Enemies. The parasites are one of the main factors in keeping *Earias* spp. in check. Nangpal (1948) lists the following natural enemies of *Earias* spp. obtained from different parts of India (Table 42). Thompson (1945) in addition to most of the above-mentioned parasites also mentions *Phanerotoma hendecasisella* Cam., as parasitizing *Earias insulana* in India.

TABLE 42. LIST OF NATURAL ENEMIES OF *Earias* spp.

Family	Species	Stage of the host parasitized	Nature of parasitism	State where recorded
Trichogrammatidae	<i>Trichogramma evanescens</i> West.	Egg	Endo-parasite	Punjab, Madras and Bombay
Braconidae	<i>Microbracon lefroyi</i> D. & G.	Caterpillar	Ecto-parasite	All over India
	<i>M. greeni</i> Ash.	"	"	Madras
	<i>M. hebetor</i> Say.	"	"	Madras and Delhi
	<i>M. brevicornis</i> Wes.	"	"	Punjab, Uttar Pradesh and Marathwada
	<i>Rhogas testaceus</i> Spin.	"	Endo-parasite	Punjab and Bombay
	<i>Rhogas aligharensi</i> Qadri	"	"	Madras
	<i>Bassus</i> sp.	"	"	Madras
	<i>Apanteles</i> sp.	"	Ecto-parasite	Bombay
	<i>Chelonus</i> sp.	Pupa	Endo-parasite	Bombay
	<i>Chelonus rufus</i> Lyle	"	"	Punjab
Ichneumonidae	<i>Melcha nursei</i> Cam.	"	Ecto-parasite	Bombay, Gujerat, Punjab, Madras and Marathwada
Chalcididae	<i>Chalcis tachardiae</i> Cam.	"	Endo-parasite	Punjab
	<i>Chalcis responsonator</i> Wlk.	"	"	Punjab
	<i>Chalcis</i> sp.	"	"	Punjab
	<i>Centrochalcis</i> sp.	"	"	Punjab
Elasmidae	<i>Elasmus</i> sp.	Caterpillar	Ecto-parasite	Punjab
	<i>Elasmus johnstoni</i> Ferr.	"	"	Madras
Tachinidae	<i>Actia aegyptia</i> Vill.	"	Endo-parasite	Punjab and Bombay
	<i>Actia hyalinata</i> Mall.	"	"	Madras
Chloropidae	<i>Polyodaspis</i>	"	"	Madras
Predators	In Madras, <i>Eumenes petiolata</i> has been observed to prey upon <i>E. fabia</i> caterpillars and stock them in its nest, built high up on the trees.			

A good deal of work has been done on the natural enemies of *Earias* spp. One of the early references in literature is the discussion at the Second Entomological Meeting held at Pusa in February, 1917, wherein mention was made of artificial introduction of endo-parasites, *Rhogas* spp., in parasite boxes in the undivided Punjab, which was found beneficial. Subsequently, in 1919, the above parasites were identified by Prof. C. T. Brues of Harvard University, as belonging to two different species—*Microbracon lefroyi* and *Microbracon* sp. A large amount of work has been carried out on the parasites of *Earias* spp., especially in the Punjab. The parasites studied in detail are the pupal parasite—*Melcha nursei* Cam., by Ahmed and Ullah (1944); *Trichogramma* spp.—egg parasites by Cherian and Margabandhu (1943); *Rhogas testaceus*, *Actia aegyptia* and *Microbracon lefroyi*—larval parasites by Deshpande and Nadkarny (1936); *Elasmus johnstoni*, *Bracon* (*Microbracon*) *lefroyi* and *Rhogas testaceus* (all larval

parasites), *Melcha nursei* and *Brachymeria tachardiae*—(both pupal parasites) by Khan and Verma (1946); *Rhogas testaceus*—larval parasite by Ahmed (1943); *Microbracon lefroyi*—larval parasite by Ahmed and Ullah (1939), and *Microbracon lefroyi*, *Rhogas aligharensi*, *Bassus* n. spp., *Elasmus johnstoni*, *Actia hyalinata*—all larval parasites by Cherian and Kylasam (1941). The parasites recorded are *Microbracon greeni*, *Elasmus johnstoni*, *Polydaspis compressiceps*, *Microbracon hebetor* and *Melcha nursei*. It may not be out of place if brief notes are given of the parasite complex of *Earias* spp.

Trichogramma spp. : Cherian and Margabandhu (1943) observed 60-100 per cent. parasitisation of *Earias fabia* eggs by *Trichogramma* at Coimbatore. Super-parasitism was not observed. The life cycle in the host eggs lasted 8 days. Field releases of parasites reduced the percentage of attack of bolls by both *Earias* spp. and *P. gossypiella*, by 22 per cent.

Microbracon lefroyi D. & G. (*Microbracon greeni lefroyi* D. & G.) : Lal (1939) regards *M. lefroyi* D. & G. synonymous with *M. greeni* Ash. It is an external larval parasite of *Earias* spp. Mating generally takes place on the day of emergence and is repeated several times during the period of their life. Normally oviposition begins on the second or third day after emergence of the female. Oviposition occurs at any part of the day time. The total number of eggs laid is the largest at 25°C. Only full-grown *Earias* spp. caterpillars are selected for oviposition and the host larvae are completely paralysed before eggs are laid. Naked larvae are generally not attacked, but only when they are in concealment. The female parasite locates the larva with its antennae, inserts her ovipositor and lays two or more eggs. Husain and Mathur (1921) state that the female punctures the body of the caterpillar usually in the abdominal region and sucks the liquid oozing from the wounds before ovipositing. Khan and Verma (1946) state that eggs are laid singly or in groups of 2-4 on any part of the body of the host. Sometimes the eggs are laid apart from the host larva. The largest numbers of eggs, over 52 per cent., are laid on the first and second abdominal segments. At Delhi during the hot weather months of July-September the female parasites begin to lay eggs on the day after emergence and continue to lay almost daily up to the day of their death. With the fall in temperature during cold weather oviposition is low and irregular. The maximum number of eggs laid by a single female varies with localities (143—Khan and Verma, 1946; 216—Husain and Mathur, 1923; 504—Deshpande and Nadkarny, 1936; 589—Ahmed and Ullah, 1941). The female parasite can lay eggs parthenogenetically also, but the resulting progeny consists entirely of males. The larval stage lasts for 2-6 days at Surat, and 5-8 days in the Punjab.

Deshpande and Nadkarny (1936) have made observations on the incidence of *M. lefroyi* at Surat. During September-October when large number of *Earias* spp. caterpillars are found in young cotton shoots the incidence of the parasite is extremely low. This is probably due to the younger stages of the

host larvae obtainable at this time. The parasites increase in number after October, and in December-January most of the larvae are attacked. In December the parasitization is as high as 90 per cent. During the heavy parasitization period of November-January, *M. lefroyi* does not attack *Earias* spp. larvae found on *Abelmoschus esculentus* but only those found on cotton.

At Coimbatore the incidence of *M. lefroyi* never exceeds 2-3 per cent. Cherian and Kylasam (1941) do not regard it as an efficient parasite. They have bred it from larvae of *Adisura atkinseni* in pods of house beans, *Rabita frontalis* in cotton bolls, and *Earias* spp. in *blendi* (*Abelmoschus esculentus*) pods. *Microbracon lefroyi* does not parasitize *Earias* spp. larvae found in the pods of *Hibiscus vitifolius*, *Acaulon hirtum* and *A. indicum*. An allied braconid, *Microbracon greeni* Ash., parasitises 8-43 per cent. of *Earias* spp. found in the pods of *Hibiscus vitifolius* throughout the year, but is not found on *Earias* spp. in cotton.

In the Punjab, Khan and Verma (1946) have made observations on the seasonal activity of *M. lefroyi* in cotton fields. They have found that the population of the parasite is highest during July-September. Between the pink and spotted bollworms, the latter are found to be more attacked by the parasite. The carry-over from one cotton season to another appears to be mostly through the adult stage.

Attempts at mass multiplication of *M. lefroyi* have been made at Surat (Deshpande and Nadkarny, 1936) and Delhi (Ahmed and Ullah, 1941). The latter authors have pointed out the difficulties in mass rearing of *M. lefroyi*. The main handicaps are :

1. The food of *Earias* spp. must always enclose the larvae, as naked larvae are not accepted by the parasite. Fresh vegetable matter being the only suitable food for the larvae, the food has to be changed frequently involving a great deal of manual work.
2. *Earias* larvae are not available in large numbers at certain times of the year unless special cultures are artificially maintained at suitable temperature.
3. Only well-developed *Earias* larvae are accepted for oviposition by the parasite and there is no real hibernation in the species. As such the suitable stage of the host for parasitization is available only for a short time.
4. No alternate host apart from *Earias* spp. is known which could be acceptable to the parasite.

Several attempts were made by the above authors to overcome these difficulties and the observations made by them are:

1. The parasite prefers only the pre-pupal stage of *Earias*.
2. *Platyedra gossypiella* larvae are suitable as an alternate host. The hibernating larvae of the long cycle moths of *P. gossypiella* are available throughout the winter, spring and early summer.

3. The parasites thrive well under temperatures varying from 13° to 16°C.

Elasmus johnstoni Ferriere: It is an ecto-larval parasite of *Earias* spp. At Coimbatore, *E. johnstoni* is a parasite of *E. fabia* infesting *Hibiscus vitifolius* pods (Cherian and Kylasam, 1941). It does not attack much of the larvae occurring in cotton or *bhendi* (*Abelmoschos esculentus*). Under laboratory conditions, the insect shows a marked preference to the cocooning caterpillars for parasitization. It occurs all through the year in limited numbers in *H. vitifolius* pods. Seven to ten parasites are found in each host larva, the highest number recorded being 98 from a single caterpillar. The population is predominantly female and their longevity does not exceed a fortnight when fed on sugar solution. The host caterpillar is paralysed by several thrusts with the ovipositors from outside, and eggs varying from 8-10 are laid in loose groups on any part of the body of the host. The egg is small and white. Pupation is naked within the host cocoon and the adults emerge within a week after pupation. The life cycle lasts for 10-12 days.

In the Punjab the host range of *E. johnstoni* includes all the three species of *Earias* and *Platyedra gossypiella*. According to Khan and Verma (1946) coitus occurs freely in captivity and lasts for about 10 seconds. The parasite locates the caterpillar inside its food and stings it from outside. Fewer eggs are laid in November when the mean temperature falls below 75°F. Parasitization may occur in the pre-pupal stage also. Parthenogenesis also occurs, progeny consisting of males only. The life cycle of *E. johnstoni* in the Punjab lasts for 10-28 days.

Rhogas testaceus Spin.: This is a braconid endo-larval parasite; its hosts include all the three species of *Earias*. Ahmed (1943) has given a detailed account of its morphology and biology. It is confined to the cotton growing tracts of northern India, like Delhi, the Punjab, Madhya Pradesh and Gujerat. Outside the Indian sub-continent, it is known to occur widely in Europe.

At Surat it is found to be present throughout the year in cotton fields except during July-August. Copulation is observed soon after emergence and lasts for about 10 seconds. Adults copulate at all hours of the day. Full-grown second instar and young third instar larvae are mostly preferred for egg-laying. Sometimes oviposition takes place in the fourth instar larvae also. First instar larvae are never attacked.

When the host larvae are concealed in the bolls and the buds of the host plant, the parasite moves up and down in search of the host. As soon as its antennae touch a mass of frass at the entrance of the larval burrow it inserts its abdomen and stings the host and paralyses it. The eggs are always laid inside the body of the host generally in the abdominal region. Usually a single egg is laid in each caterpillar although more than one egg is observed

in a few cases. The fecundity of the parasite is low, the maximum number of eggs laid by a female being only 83.

The longevity of the female parasite varies from 7-35 days, depending upon temperature and food.

The life cycle of the parasite is greatly influenced by temperature and the internal physiological conditions of the host. It varies from 10 days in September to 35 days in January.

Ahmed (1943) states that, although *R. testaceus* breeds throughout the year and has a very short life cycle, it is not very important in the control of *Earias* spp. because of its low fecundity, and about 25 per cent. mortality in its pupal stage. Moreover no other suitable host except *Earias* spp. is known yet on which it could be conveniently mass bred.

Rhogas aligharensi Qadri: This species was first described by Qadri (1933) from specimens taken from affected larvae of *P. gossypiella* Saund. and examined by Prof. Bischoff of Germany. In Coimbatore it is a specific endo-larval parasite of *Earias* spp. that infest cotton buds, bolls and *A. esculentus* pods. It is very active in December-January when the host population is highest. A single adult emerges from the affected host.

Actia aegyptia Vill. and *Actia hyalinata* Mall: The former has been noted at Surat and the latter at Coimbatore. Both are minor parasites. The maggots come out of the body of the host and transform into puparia from which the adults emerge after a week.

Bassus n. spp.: These are endo-larval parasites of caterpillars of *Earias* spp., infesting tender and medium bolls of cotton, but not reared so far from the same hosts in other host plants. Only a single parasite emerges from each host caterpillar. These species are found in January in Madras. They have not been described so far.

Melcha nursei Cam.: This is one of the important external pupal parasites of *Earias* spp. Its distribution is mostly confined to northern India. A detailed account of its biology has been worked out by Ahmed and Ullah (1944). Its efficiency in controlling *Earias* spp. cannot be rated as high because of the preponderance of male population over female, which the authors found to be as low as 5 per cent., and the narrow temperature range required for its optimum development although the parasite is able to paralyse and kill a much larger number of hosts than those actually oviposited upon.

After stinging the pupa the parasite lays eggs between the cocoon and the body of the pupa. The number of eggs laid by a female parasite varies from 5-51. Pruthi (1939) states that sometimes 150 hosts are paralysed. Incubation period ranges from 0.8-2.93 days, grub stage 3-9 days and pupal stage 7-38 days, depending upon temperature and humidity. It is probable that when more than one egg is laid one grub survives, while the rest die for want of sufficient food.

Brachymeria tachardiae Cam.: This is an internal pupal parasite of all the

three species of *Earias*. After stinging the host the eggs are laid in the thoracic region. Each pupa contains only one egg. Both the male and female parasites are short-lived but with the fall in temperature during winter, the longevity increases. At Rohtak in the Punjab, the total life cycle is completed in just over 11 days in June, thereafter it increases with the fall in temperature.

The parasite grub is dirty grey to white in colour. It lies horizontally in the body of the host, its head pointing towards the anterior end of the host. When full-fed the grub stops feeding for about 24 hours before it pupates.

Alternate Host Plants. *Earias fabia* and *E. insulana* are observed, apart from cotton, on a number of other host plants. Common among them are *Abelmoschos esculentus*, *Hibiscus sabdariffa*, hollyhock (*Althaea rosea*), *Hibiscus panduraeformis*, *Abutilon indicum*, *Abutilon graveolens*, and *dev-kapas* (tree cotton). Amongst the above, *Abelmoschos esculentus* is noted to be the most important alternate host. Fletcher and Misra (1919) at Pusa have observed *Earias* spp. on *H. rosa-sinensis*, *H. cannabinus*, *Abutilon indicum*, and *Althaea rosea*. Sawhney and Nadkarny (1943) mention that *A. esculentus* and *ambadi* (*Hibiscus cannabinus*) grown as irrigated vegetables are the principal alternative host plants that carry the *Earias* spp. in the absence of cotton plants in Marathwada and suggest that they should not be allowed to be grown during April-June. Walker and Meymarian (1954) in Iraq have recorded the following alternate hosts apart from cotton:

Abelmoschos esculentus (L.) Moench.

Hibiscus cannabinus L.

Althaea rosea L.

Abutilon theophrasti Medic.

Malva parviflora L.

Hibiscus rosa-sinensis L.

In the Punjab, Khan, *et al.* (1946) have recorded the following alternate hosts: *Abutilon indicum*, *Althaea rosea*, *Hibiscus cannabinus*, *Abelmoschos esculentus*, *Malva parviflora*, *M. sylvestris*, *Malvastrum tricuspidatum* and *Sida cordifolia*. *Earias insulana* seemed to prefer *Abutilon indicum*, and *E. fabia* chiefly attacked *Abelmoschos esculentus*.

It is apparent from a study of alternate host plants that some of them serve as effective carriers for *Earias* spp. for tiding over periods when cotton is not available in the field. Amongst them, *bhendi* or okra appears to be the most important.

Control Measures. Most of the control measures tried so far have been preventive since the bollworms are internal feeders. Details of the control measures tried against *Earias* spp. are given below:

CULTURAL AND MECHANICAL:

- (i) Removal of first affected shoots and bolls.
- (ii) Trap cropping.

(iii) Attractants and deterrents.

(iv) Removal of *A. esculentus* and other alternate host plants (including stray cotton plants) during the off-season.

(v) Complete removal of cotton stalks as soon as the final picking of cotton is over.

(vi) Breeding resistant varieties.

Removal of First Affected Shoots and Bolls: Ayyar (1932) recommends destruction of the first attacked shoots and bolls to prevent the multiplication of the pests. Deshpande and Nadkarny (1936) have observed that only such shoots, whose damage can be easily noticed, can be collected by this method and that there could be very large percentage of population left out in the field as the damage caused by them is not easily perceptible to the ordinary cultivator. In the Punjab, the method of dragging a rope over the top portions of the cotton plants in June-July (sowing being done in March) was tried and this resulted in dropping of flowers. The field was irrigated thereafter when the larvae and pupae of bollworms got drowned in the water. This method is said to be comparatively more effective and cheaper than picking up of the individual infested buds and bolls.

Trap Cropping: *Abelmoschos esculentus* is another principal alternate host plant of *Earias* spp. Fletcher and Misra (1920) carried out observations with *A. esculentus* and *Cajanus indicus*. He found that the latter plants became so bushy, that they interfered seriously with the growth and subsequent bolling of the cotton. Although *A. esculentus* proves to be an excellent trap crop, there is great difficulty in inducing the cultivators to pull the plants up at the proper time, it being more valuable at times than cotton.

Deshpande and Nadkarny (1936) felt that *A. esculentus* could be a very good trap crop if it could be grown even after October. They tried delayed sowings with a number of varieties and observed that sowings of a mixture of the varieties Nasik and Surat 5 at the commencement of south-west monsoon would give a continuous stand of plants for trapping *Earias* spp.

In spite of its higher attraction to *Earias* spp. growing of *A. esculentus* in cotton fields is not advocated by Deshpande and Nadkarny (1936) on the following grounds:

1. Difficulty in ensuing concerted action for the cultivators in picking out and destroying the affected *A. esculentus* plants at regular intervals before the larvae feeding on them go to the soil for pupation.
2. Acceleration of the multiplication of *Earias* spp. on *A. esculentus*.
3. Immunity of *Earias* spp. larvae in *A. esculentus* pods by the important larval parasites—*Microbracon greeni*, *M. lefroyi* and *Actia aegyptia*.

Thus, it is not advantageous to grow *A. esculentus* in cotton areas.

Attractants and Deterrents: Fletcher and Misra (1919) reported that *Earias* moths are not attracted to light traps set in the cotton fields. Deshpande

and Nadkarny (1936) have also shown that *Earias* moths are neither attracted to light nor to the aromatic substances such as amyl acetate, methyl lutreate, acetic acid, formaldehyde, clove oil, ammonia, ammonium carbonate, etc., although a few moths do come to light at night.

Removal of A. esculentus and Other Important Alternate Host Plants During the Off-Season: Prevention of the carry-over of the *Earias* spp. through the stand over cotton plants and alternate host plants is an important measure of control. Cultivation of a single cotton crop in the season is advocated instead of two crops to prevent the heavy multiplication and outbreak on the succeeding cotton crop. Ayyar (1932), working in Madras, has stressed the inadvisability of growing *A. esculentus* when there is no cotton in the field. Sawhney and Nadkarny (1942) do not recommend the cultivation of *A. esculentus* and *H. sabdariffa* as vegetables from middle of April to middle of June.

Nadkarny (1951) suggested that the cotton growing tracts should be earmarked either for the *kharif* or the *rabi* crop according to suitability.

Removal of Cotton Stalks Soon After Harvest: This is one of the most important measures of control that is advocated for the control of *Earias* spp. Sawhney and Nadkarny (1942) and Nadkarny (1951) have reported the large scale trial of the removal of cotton stalks after picking before the end of March in Nanded district of Bombay. According to their observations the initial rate of infestation of *Earias* spp. is lower in the treated areas than in the untreated areas, but they also strike a note of caution that wholesale application of the control is essential for their effectiveness. Sharma and Mohindra (1948) have also conducted large scale trials in Tharparkar and Hyderabad districts of Sind Province in undivided India and have reported that *Earias* spp. were practically absent in the cleaned area wherein removal of cotton stalks had been done from May to July each year. During August to November the attack on buds and bolls in the treated areas was 3-5 times less than that obtained in an uncleaned area. The yield of *kapas* was also higher by about 20 per cent. on an average and there was also a great improvement in the quality of *kapas*. Patel's (1949) observations in Baroda pointed out that damage caused by the spotted bollworm, *E. fabia*, could be much reduced if the cotton plants or stalks are uprooted or cut before 15th May, close to the ground where uprooting is difficult, so as to leave no stumps. A special plant puller has also been devised by him for removal of the plants from the ground with roots, since the local practice of chopping plants at ground level results in the production of adventitious shoots from the roots and the pest tides over the off-season on these shoots. Large scale application of the above control measures under a legislative act termed 'Baroda State Agricultural Pests and Diseases Act, 1940' has shown that the estimated damage by *E. fabia* was reduced from a range of 20-69 per cent. to as low as 0.5-1.9 per cent. and that there has been an increase in the yield of cotton crop by about 19 per cent.

Breeding Resistant Varieties: A number of varieties and species have been reported as resistant to *P. gossypiella* like *Gossypium trilobum*, *Gossypium hirsutum* var. *punctatum*, *Gossypium thurberi*, etc., and some of the varieties evolved as a result of crossing with the above wild species. In India, as shown by Husain and Khan (1940), the *desi* cottons of the Punjab are less attacked by the pink bollworm than the American varieties. In the case of *G. hirsutum*, experiments have shown that the pink bollworm larva exhibits a strong distaste for the seed and that the plants remain almost or completely free of attack even though adjacent commercial cottons are attacked. Similar observations have been made with another wild species *G. armourianum* from the New World and with *G. somalense*, native of Somalia and the Sudan. Reports of resistance to *Earias* spp. are, however, very few. Four wild species, namely, *G. thurberi*, *G. somalense*, *G. armourianum* and *G. raimondii* are reported to be resistant to *Earias insulana* in the Sudan (Painter, 1951). It is also reported that breeding for resistance to *E. insulana* is in progress in the Sudan.

INSECTICIDAL CONTROL: Deshpande and Nadkarny (1936) tried a number of insecticides for the control of *Earias* spp. Earlier trials with Lead arsenate and Paris green used both as sprays and dusts revealed that they were not effective in reducing the incidence, but on the other hand, Paris green had a phytotoxic effect on the plants. Later, tests with calcium arsenate with and without dilution with slaked lime showed that treated plants had lesser incidence than the control, especially in plots dusted with calcium arsenate without dilution. But, a serious drawback in the case of calcium arsenate dusting was the unusually heavy infestation of *Aphis gossypii* which lowered the yield of *kapas* in treated plots. Further experiments were conducted with blackened sodium silico-fluoride. The latter insecticide was found to be more effective in reducing the *Earias* population. It was also found that blackening of the insecticides did not entirely prevent *Aphis* infestation. The yield of *kapas* from plots dusted with blackened insecticide was greater than the control plots. It was concluded that both calcium arsenate and sodium silico-fluoride could be useful in controlling *Earias* spp., provided the *Aphis* infestation is controlled by some means.

Patel, *et al.* (1955) used a spray of 0.2 per cent. DDT applied eight times at weekly intervals without success. They found that 0.2 per cent. toxaphene reduced infestation from 62.9 per cent. to 58.5 per cent. but this did not affect the average yield. Later experiments using 0.05 per cent. endrin, 0.4 per cent. toxaphene and their mixture and 0.2 per cent. DDT, all at 130 gallons per acre, reduced the average infestation from 60.3 to 33.3, 41.3 and 40.3 per cent., respectively, and resulted in substantial yield increases.

Maheswariah and Puttarudriah (1956), in Mysore State, recommend clipping the tender withering and drooping twigs and destroying them, collection and destruction of infested bolls, dusting of gammexane D. 025 on

young and tender leaves and bolls, and selection of healthy seeds for planting.

Thirumala Rao, *et al.* (1954), in Andhra Pradesh, advocated spraying parathion at 0.025 per cent. and endrin 0.03 per cent. in two or three rounds at fortnightly intervals, after the pest begins to appear. In Assam, Chowdhury and Majid (1954) recommended dusting with a mixture of DDT 5 per cent. and BHC 5 per cent., the first dusting to begin by the middle or end of May. In Iraq, Walker and Meymarián (1954) have conducted field experiments against *E. insulana* Boisd. with endrin, dieldrin and toxaphene and have found treatment with endrin at both 0.5 lb. and 1.0 lb. per acre to give significantly better bollworm control than either dieldrin or toxaphene. They have found, however, a build up of *Tetranychus* spp. in plots treated with endrin or dieldrin for which they have recommended application of sulphur. Nadkarny (1955) conducted trials with DDT, BHC, calcium arsenate and 'cotton dust' at Indore and found that spraying with 0.25 per cent. DDT and 0.25 per cent. BHC, and dusting with cotton dust gave fairly adequate protection against *Earias* spp. Abraham and Bashir (1958) found that both endrin and parathion are almost equally effective in controlling the spotted bollworms. One hundred gallons of spray fluid containing 0.6 lb. of endrin and 0.7 lb. of parathion, sufficed for one acre, the rounds of spraying being carried out at tri-weekly intervals commencing when the crop is nine weeks old.

BIOLOGICAL CONTROL: Although a good number of parasites have been recorded on *Earias* spp. and much fundamental work done on the biology of the parasites under laboratory conditions, information regarding actual rate of parasitism occurring in the field in different areas is fragmentary. That the natural enemies play an important part in keeping the bollworms in check has been shown in several countries in recent years. The use of insecticides to control other pests has resulted in increased damage by bollworms due to their natural enemies being killed by the insecticides used, e.g., in Egypt, the Sudan, etc.

Attempts so far made in India to control bollworms biologically have been by using indigenous natural enemies. Ayyar and Margabandhu (1934) indicated Hymenopterous parasites of economic importance in South India suggesting their utilisation in the control of various pests including bollworms of cotton. Cherian and Margabandhu (1943) have given an account of preliminary trials made by them using *Trichogramma minutum* Riley in the control of cotton bollworms in Madras State. Weekly releases of other parasites in the Central Farm, Coimbatore, as a trial have also been reported with a certain amount of success, but it is not known whether the work was followed carefully and the results statistically analysed properly. Simmonds (1960) has deprecated the tendency in India to lay stress on the utilization of indigenous natural enemies rather than on the investigation and introduction of exotic species of natural enemies from foreign countries.

Attempts have been made in some cotton growing countries to control bollworms, both *Earias* spp. and *Platyedra gossypiella*, by introducing their natural enemies from other countries, but so far with little success. One of the notable examples is the attempt made by the U.S.A. to import parasites from the East Africa, Hawaii, Korea and Brazil. As stated by Clausen (1956), eleven species were introduced between 1934 and 1943 but they failed to establish themselves because the releases had been made in semi-arid areas where cotton is grown in irrigated fields and where very few alternate host plants are available. The clean-up programme and the cotton-free period enforced as a control measure eliminated a large percentage of the hosts that would normally hibernate and of the parasite as well, and also in the absence of alternate hosts on which to bridge the intervening period, the parasite colonies appear to have died out. Alfieri (1928) has given details of the introduction of *Microbracon kirkpatricki* Wilkn. into Egypt from Kenya. According to Kamal (1936) in an area where over 50,000 had been released every year, the numerical ratio of host and parasite was not affected possibly due to adverse weather conditions, particularly the cold winters and nights as well as the resting stage of the host. *Microbracon lefroyi* D. & G. from India, *M. mellitor* Say. from Hawaii, and *Trichogramma minutum* had also been introduced. *Microbracon kirkpatricki* did not give positive results in Barbados against *Platyedra gossypiella* (Tucker, 1936).

The above-mentioned few attempts and the failures obtained have not detracted entomologists from making further trials to control the bollworms biologically. The U.S.A. has renewed its search for natural enemies and has in recent years introduced some species from India. 'The Commission internationale de lutte biologique contre les ennemis des cultures' is presently working on the biological control of bollworms in Spain, Morocco, West Africa and Iran. Thompson (1945, 1946) has listed the parasites of *Earias* spp., and *Platyedra gossypiella*. The parasites and predators of the spotted and pink bollworms in Africa have been listed by Pearson (1958). The introduction and trial of parasites and predators which do not already occur in India is worthwhile. *Microbracon kirkpatricki* exercises a fair measure of control in East Africa (Kirkpatrick, 1927). In Mexico, parasitism as high as 75 per cent mainly by *Bracon platymatae* (Cushm.) has been recorded (Rude, 1937). These and other promising parasites from different countries should be introduced and tried in India.

Diseases caused by *Bacterium gelechiae* and *B. rubrum* have been recorded on *Platyedra gossypiella* in Egypt, *Bacterium ephesitiae* (from *Ephestia*) and *B. gelechiae* as stated by Pearson (1958) gave quite promising results, but there was little spread of the diseases beyond the sprayed areas (Metalnikov and Metalnikov Jr., 1932, 1933). *Bacillus pectinophorae* has been recorded by White and Noble (1936) as pathogenic on the larvae of *Platyedra gossypiella* in the laboratory but has not been detected by them in the field. No insect pathogens

have been recorded so far in India either on the spotted or pink bollworms. It would be worthwhile making a study of the diseases that attack bollworms in India and experiment upon the possibility of their utilisation in the control of the pests.

In a case like this, where several countries are interested in the control of bollworms, a more concentrated and sustained effort is necessary with a view to making a search for and exchanging natural enemies between one country and another. Such an exchange, if undertaken at the same time under an international organization, would not only facilitate work and yield better results, but will also make the project less expensive than when individual countries undertake the work at different times. Detailed surveys, if undertaken by each country interested in the project, are likely to bring to light more natural enemies including insect pathogens than are at present known to exist, some of which may prove useful to other countries.

LEGISLATIVE CONTROL: Legislative measures have been adopted in some places, especially regarding cleaning up of cotton stalks after picking. In Madras the Pest Act for Cotton Pests Control (mostly for bollworms) was enforced as early as 1919, according to which all Cambodia cotton stalks have to be pulled out before the 1st August, and that no cotton could be grown for a month (Ramachandra Rao, 1929). This is said to have done considerable good in keeping down the pest infestation. Mention has already been made of 'Baroda State Agricultural Pests and Diseases Act, 1940' under which, since 1943-44, it is compulsory for every cotton cultivator to uproot the cotton stalks before 15th May to avoid sprouting of leaves from 15th May to 15th June. This has helped in keeping down the infestation of *Earias fabia* to negligible levels.

Summarising, it may be stated that no single measure has been found to be effective for the control of *Earias* spp. in cotton. The usefulness of cultural and mechanical measures especially uprooting of cotton after picking and avoiding of raising of alternate host crops like *Abelmoschos esculentus* during the off-season has been amply demonstrated. This coupled with timely chemical measures is likely to prove of immense benefit to cotton growers. At the Institute of Plant Industry, Indore, the interspecific hybridisation of *Gossypium thurberi*, which is reported to be resistant to *Earias insulana*, with cultivated cotton has been in progress (Ganesan, 1952). It remains to be seen whether any of these hybrids would prove resistant to *Earias* spp. Legislative enactments in all cotton growing States making it compulsory for the farmers to uproot cotton stalks soon after harvest within a specified date and also not to grow alternate host crops during the off-season would go a long way in keeping down these pests.

Before concluding the account of *Earias* spp., it is necessary to make a brief mention of the third species, namely, *Earias cupreoviridis* Walk. It is known as a pest of cotton in China, Formosa and the Philippines. A brief

account of its biology has been given by Khan (1947) under conditions obtaining in Delhi. It remains active from April to October hibernating for the rest of the year in the pupal stage. It has been observed only on *Sida grewoides* which is a common weed. It is also recorded on jute, some species of *Hibiscus*, *Sida cordifolia*, *Malvastrum tricuspidatum* and *Althaea rosea*.

Heliothis armigera Hübn.

Heliothis armigera is another minor bollworm. Under the name, *Heliothis* (*Chloridea*) *obsoleta* Fb., it was first described as a pest of cotton by Ballard (1920), and later by Ayyar (1932), in Madras. It has a large number of host plants besides cotton.

Maheswariah and Puttarudriah (1956) recommend spraying with calcium arsenate or dusting infested crop with DDT 5 per cent. or gammexane D. 025 to reduce the damage by this pest.

Thompson (1946) has listed: (i) *Apanteles ruficrus* Hal.; (ii) *Atractodes* sp.; (iii) *Chelonus* sp.; (iv) *Microbracon brevicornis* Wesm.; (v) *Microplitis* sp.; and (vi) *Trichogramma* sp. as parasites of this species in India.

Rabila frontalis Wlk.

This is another bollworm of cotton which was first noted by Ballard, attacking bolls at Udumalpet (Coimbatore district) and at Alinagaram (Madurai district) in 1920 and later by Ramchandra Rao (1924) attacking indigenous perennial cotton in Coimbatore and Salem districts. It has been recently recorded as a pest on Sea Island cotton in Madras State by Ramchandra Rao (1952). He (1924) has found *Bracon* sp. parasitizing the caterpillar stage of this pest.

COTTON LEAF ROLLER, *Sylepta derogata* Fb.

The cotton leaf roller is one of the important sporadic pests of cotton and occurs throughout India. It is also reported from many of the cotton growing countries of the world, like East Siberia, Africa, Java, China, Japan, Burma, Ceylon, Australia, etc.

Though a minor pest, it is reported to have caused severe damage to the cotton crop in Kanpur area in Uttar Pradesh during 1895, 1900, 1927, 1942 and 1945, especially on Perso-American cottons (Lal and Singh, 1951), and in the Punjab in 1956. A comprehensive account of *S. derogata* has been published by the above authors. Its life-history and biology in Bengal have been studied by Sen (1928) (Plate XIII).

The nature of damage to the cotton crop consists of the caterpillars rolling the leaves and feeding on the epidermis of the leaf when young and eating up of a large portion of the leaf later. In case of severe attack, the plants may be entirely denuded of leaves and the crop may fail completely. As many as 32 young caterpillars may be found inside a single leaf roll, but

as they grow, they disperse. Lal and Singh (1951) have studied the factors affecting the incidence of *S. derogata* and found that low temperature, high humidity and a number of cloudy and rainy days during the *kharif* season favour the hibernation of the larvae, resulting in an outbreak of the pest in the next season. This is also due to the increase in the initial population of caterpillars. As regards the incidence on different periods of sowing, pre-monsoon sowings show a greater incidence of *S. derogata* than the post-monsoon sowings. The crop receiving a larger amount of nitrogenous fertiliser (150 lb. N) shows a greater incidence of the leaf roller than the crop receiving a smaller amount (50 lb. or 0 lb. N).

Life History. The eggs are singly laid on the lower surface of the leaves, a female moth being capable of laying as many as 200 eggs. The incubation period varies from $2\frac{1}{2}$ - $3\frac{1}{2}$ days. The larval period ranges from 15-20 days, and the larvae undergo six moults before pupation. Pupation occurs on the plants inside rolled leaves or less frequently on the ground among fallen leaves or in the soil about the time of hibernation. The pupal period lasts from 6-12 days.

In Uttar Pradesh, *S. derogata* is first observed in the last week of June or in the first week of July on Perso-American cottons. The moths lay eggs and caterpillars are observed rolling leaves from the second week of July to the end of November. September is the month of maximum activity. From October onwards their activity declines and at the end of November or beginning of December, nearly all full-grown caterpillars go into the soil for hibernation and aestivate during summer. The aestivating caterpillars transform into pupae usually sometime in June, depending on temperature and humidity then prevailing. Moths emerge usually towards the end of June, and lay eggs mostly on the cotton crop. During the period July-November, there are four somewhat overlapping generations, followed by a fifth generation, the caterpillars of which hibernate.

Alternate Host Plants. Apart from cotton, *S. derogata* is known to feed and develop on a variety of hosts, like *Abelmoschos esculentus*, *Urena lobata*, *Althaea rosea*, *Abutilon indicum*, *Sida cordifolia*, *Kida calycina*, *Achryanthus aspera*, *Corchorus* spp., and *Hymenodictyon excelsum*.

Natural Enemies. Thompson (1947) has listed the following species as parasitizing *S. derogata* in India:

- Bessa remota* Aldr. (Dipt. Tachinid)
- Brachymeria tachardiae* Cam. (Hym. Chalcid)
- Elasmus indicus* Rohw. (Hym. Elasmid)
- Enicospilus atricornis* Morl. (Hym. Ichneumonid)
- Goryphus nursei* Cam. (Hym. Ichneumonid)
- Microbracon lefroyi* D. & G. (Hym. Braconid)
- Microtoridea lissonota* Vier. (Hym. Ichneumonid)

Phanerotoma hendecasisella Cam. (Hym. Braconid)

Trichospilus pupivora Ferr. (Hym. Eulophid)

Xanthopimpla punctata F. (Hym. Ichneumonid)

He also includes in the list a number of other species of parasites attacking the pest in other countries.

Cedria paradoxa Wilk., has also been found to breed on this species in the laboratory in Uttar Pradesh.

Lal and Singh (1951) record the following parasites of *S. derogata* in Uttar Pradesh:

Xanthopimpla spp.

Apanteles spp.

Brachymeria tachardiae Cam.

To the above may be added *Neopimploides syleptae* Viereck, recorded by Usman and Puttarudriah (1955) and *Microtoridea lissonota* Vier., by Maheswariah and Puttarudriah (1956), in Mysore. In Madras and Andhra two species of *Apanteles*, *Microbracon* spp. and *Elasmus* spp., have been noted on *S. derogata* larvae; *Xanthopimpla* spp. on pupae; and *Trichogramma* spp. on eggs.

Husain and Bhalla (1937) have given a list of bird enemies of the cotton leaf roller in the Punjab. According to them, 36 different species of birds predate on *S. derogata* caterpillars. Of these, 12 species were found to be of great importance, the most effective being the Himalayan Starling, *Sturnus vulgaris* Kumii, individuals of which ate on an average 162 larvae a day.

Control Measures. Lal and Singh (1951) have recorded that the variety 10F suffers less from the attack of *S. derogata* than the others. Light traps for catching adult moths have not been found effective. Ploughing of the lands between December and June and destruction of crop remnants after harvest is found to be a useful control measure. Removal of rolled leaves in July and early August is quite effective.

A number of insecticides have been used earlier both in India and abroad for the control of *S. derogata*, and these are Paris green, lead arsenate, lime, soap, calcium arsenate and sodium fluosilicate. Lal and Singh (1951), after extensive trials in Uttar Pradesh, have recommended spraying with 0.5 per cent. BHC or DDT. Five per cent DDT or BHC dusts have also been found to be satisfactory. Thirumala Rao, *et al* (1954) recommended spraying BHC 0.05 per cent. in two or three rounds or parathion 0.025 per cent. In Madhya Pradesh, Gupta and Joshi (1955) recommended dusting with 5 per cent. DDT or BHC. In Madras, trials with different formulations of DDT and BHC, pyrodust, etc., have shown that BHC is effective against only the young caterpillars. Srivastava (1959) recommends spraying with 0.5 per cent. DDT or BHC suspension. The DDT-BHC mixture, endrin and dieldrin were found to be effective against leaf rollers and semiloopers.

Of the three, endrin (2.55 per cent. of 19.5 emulsion) gave the best result.

Maheswariah and Puttarudriah (1956) recommend dusting gammaxene D.025 on young plants when the first symptoms of rolled leaves are seen. Patel, *et al.* (1956) recommend: (i) removal and burning of all rolled-up leaves containing the caterpillars, which is the simplest method of control; and (ii) if the infestation is heavy, dusting with 5 per cent. BHC or DDT.

COTTON SEMILOOPERS, *Anomis flava* Fab., *Acontia graellsii* Fsth.,
Tarache notabilis Wlk., *T. nitidula* F., *T. basifera*
Wlk., and *T. opalinoides* Sn.

Six species under the category of semiloopers are known to infest cotton crop. They are all minor pests, doing damage occasionally. In the order of importance, they are: *Anomis flava*, *Acontia graellsii*, *Tarache notabilis*, *T. nitidula*, *T. basifera* and *T. opalinoides*. The damage is done by the caterpillars which eat up the entire leaf tissue leaving only the veins behind. Sometimes they injure the tender shoots, buds and bolls. Some of the alternate hosts on which these semiloopers breed are *Abelmoschos esculentus*, *Corchorus* sp., *Hibiscus parviformis*, *Sida* sp., hollyhock, etc. (Plate XIV).

Anomis flava occurs in an epidemic form in years of heavy rainfall. Its life and seasonal histories have been worked out in Mysore and Bombay. Under room temperature, during November-December, the incubation period lasts for 4-5 days, first instar 6-9 days, second instar 2-6 days, third instar 2-3 days, fourth instar 6-8 days, and pupal period 8-9 days. Moths live and lay eggs for 12-13 days.

Puttarudriah and Maheswariah (1958) have given their observations on the life-history and habits of the pest in Mysore State. They have found application of 5 per cent. BHC giving satisfactory control of the pest.

The parasites recorded are *Carcelia hockiana* Towns., *Sturmia macrophallus* Bar., *Apanteles* sp., *Tetrastichus ayyari* Rohw., *Trichogramma minutum* Riley, *Actia monticola* Mall., and *Exorista apicalia* Bar. In the field collections made by Puttarudriah and Maheswariah (1958), they found 60 per cent. of the larvae parasitized by a Tachinid, *Isyrope* sp. They also state that in the laboratory, fresh eggs are parasitized by *Trichogramma minutum* and pupae by *Tetrastichus ayyari*.

Continuous wet weather during the growing season is considered to be favourable for the rapid multiplication of *Acontia graellsii*.

Patel (1951) observed that the cotton semilooper, *Tarache notabilis*, was an important pest in Amreli district of Bombay State. With the first showers of monsoon, the moths emerge and lay eggs of the first generation on cotton plants. Cotton sown two weeks after the first monsoon shower escapes the pest attack. If the sowing is done in June, damage due to cotton semilooper is less in the thickly-sown field than in the thinly-sown one.

Some information is available on the life and seasonal histories of *Tarache*

notabilis. The eggs are round and are laid singly on the underside of the leaves. The eggs hatch in 2-4 days. The caterpillars are dark green or brown in colour and are about 1-1½ inches long when full-grown. The larval stage occupies 9-16 days. Pupae are chocolate brown in colour and pupation occurs in earthen cells in the soil about 1½ inches deep. The pupal stage lasts for 5-14 days. In the Punjab, all stages of the pest are found during April-October. In Bombay and Madras, the insect activity starts after the break of wet weather in June-July. The caterpillars are parasitized by *Thrycolyga sorbillans* Wd. and *Actia monticola* Mall. Thompson (1944) mentions in his list the Tachinid parasite, *Exorista civiloides* Bar., records of which are present in the British Museum. Apart from *Tarache notabilis*, other species of *Tarache*, namely, *T. nitidula*, *T. opalinoides*, and *T. basifera* have also been recorded on cotton. *Tarache nitidula* F. causes serious injury in certain years in South India. Its life-history has been studied by Venugopal (1956). In tests of sprays for control using 0·1 per cent. BHC, aldrin and dieldrin, he obtained 100, 60 and 63 per cent. mortality of larvae, respectively, in 48 hours. The DDT was less effective.

Some of the earlier methods of control recommended against semiloopers are the hand-picking of caterpillars in early stages and dusting with Paris green, or spraying or dusting with lead arsenate.

Khan (1956) found lead arsenate at 1-1½ ounces per gallon and DDT at 0·025 per cent. concentration to be quite ineffective. Endrin 19·5 per cent. emulsion at 0·033 per cent. is very effective.

COTTON BUD MOTH, *Phycita infusella* Meyr.

Generally this is a minor pest of cotton and is widely distributed. However, in Surat district of Bombay State, it is known as a major pest and is serious during July to October-November, while in the Punjab, it is serious in June-July. Its incidence was studied by Deshpande and Nadkarny (1936). It usually attacks indigenous cottons. The nature of damage consists of the larva feeding under cover of leaves tied together by silken threads. The attacked leaves wither, dry up and drop off. This checks the growth of the attacked plants. The eggs are round and are laid on the tender leaves of the top shoots of cotton plants. They hatch in seven days. The full-grown caterpillar is 1/2 to 3/5 inch long and is of greenish colour with faint brown stripes on the body and with black head and pronotum. The pupa is dark brown in colour with hair at the tip of the abdomen. Apart from cotton, *P. infusella* has been recorded on *Hibiscus sabdariffa*. Nangpal (1948) states that the caterpillars are parasitized by *Microbracon kitcheneri* Willcocks and *Microbracon* sp. Thompson (1946) lists *Apanteles* sp., *Chelonus* sp., *Euchalcis* sp., *Microbracon brevicornis* Wesm., *M. lefroyi* D. & G., and *Onchocalcis rufescens* Cam., as parasitizing this species in India.

Control measures recommended against this pest by Maheswariah and Puttarudriah (1956) are collection and destruction of the withered leaves.

HAIRY CATERPILLARS, *Euproctis fraterna* Moore, *E. lunata* Wlk.,
Amsacta albistriga, *A. moorei* Swinho., and *Pericallia ricini* F.

Five species of hairy caterpillars appear as occasional pests on cotton. They are: *Euproctis fraterna*, *Euproctis lunata*, *Amsacta albistriga*, *A. moorei*, and *Pericallia ricini*.

The eggs of *E. fraterna* are round in shape and creamy yellow in colour. They are laid in masses and are covered with buff-coloured hairs derived from the anal tuft of the female. The newly hatched caterpillars are slender, hairy, yellowish in colour and are gregarious. The full-fed caterpillar is elongated and stout, having a dark reddish brown colour, with the head and prothorax of light orange red colour. Pupation takes place between leaf folds, and the pupa which is reddish brown is enclosed in a coarse cocoon made up of hair and silk. The caterpillars destroy the leaves.

A number of alternate hosts exist for *E. fraterna*, like castor, banana, cow-pea (*Vigna catjang*), *Cajanus indicus*, etc.

Natural enemies of *E. fraterna* include *Aholens euproctiscidis* Mani on eggs and *Apanteles significans* Wlk. on larvae. Thompson (1945) has listed *Apanteles* sp., *Disophrys* sp., *Enicospilus* sp., *Enicospilus merdarius* Grav., and *Euplectrus ceylonensis* How., as parasitizing this species in India. The same author mentions *Apanteles* sp. and *Stenobracon deesae* Cam. as parasitizing *E. lunata* in India.

Amsacta spp. are popularly known as the red hairy caterpillars.

Amsacta moorei has been found feeding on a number of plants both cultivated and wild in the Punjab, Bombay, Uttar Pradesh, Delhi and Madras. As a pest of cotton, it has been responsible for a lot of damage to early-sown varieties of cotton in North Gujerat and to cotton sown in red soils in Madras.

The eggs of this moth are round and light yellow in colour. They are laid in clusters of 97-880 eggs usually on the underside of leaves of its host plants. The young caterpillars are brownish black in colour, while the full-grown caterpillars which are 2-2½ inches in length are orange or black in colour with their body densely clothed in long urticating hairs which arise from distinct tubercles. The pupae are chocolate brown in colour.

The adults appear on the wing between mid-June and mid-July depending upon a fairly heavy shower of monsoon rains. The female moth can lay more than 1,500 eggs which hatch in 2-3 days. The young caterpillars are active and when young, feed gregariously on the leaves of the host plants and migrate from one field to another in large hordes. A caterpillar is full-grown in 15-23 days and then it enters the soil to a depth of nine inches where it prepares a chamber in which pupation takes place.

Amsacta albistriga is very common in South India. With the first showers of monsoon, the moths emerge and lay eggs on the early-sown *kharif* crops and grasses. If cotton is sown in time, eggs are also laid on it, otherwise eggs laid on other *kharif* crops hatch, and later, caterpillars attack cotton seedlings. Usually the damage is very severe necessitating resowing of cotton. Two generations of the pest have been noticed. It is the second generation which is destructive to cotton. Caterpillars pupate in the soil and emerge only with the onset of the next south-west monsoon.

Natural Enemies. The following parasites have been listed by Thompson (1944) from species of *Amsacta albistriga* and *Amsacta* sp., in India:

<i>Apanteles</i> sp.	}	Hymenoptera
<i>A. obliquae</i> Wlkn.		
<i>A. colemani</i> Vier.		
<i>A. creatonoti</i> Vier.		
<i>Trichogramma</i> sp.	}	Diptera
<i>Sturmia inconspicuoides</i> Bar.		

Control Measures. Methods recommended are hand-picking and destroying of egg masses and caterpillars and dropping them in water with a film of kerosene oil on the surface. No effective chemical measure for the control of red hairy caterpillar has been evolved yet. Insecticides like BHC, DDT and parathion have not been effective against the grown-up caterpillars. Dusting with 10 per cent. BHC and spraying with 0.25 per cent. BHC have been found effective against young caterpillars only.

COTTON STEM WEEVIL, *Pemphres affinis* Fst.

Next to cotton bollworms, the stem weevil is very important, especially in Madras State, where a good deal of work has been done on the bionomics, natural enemies, alternate host plants and varietal resistance (Plate XV).

One of the earliest descriptions of this species is by Lefroy (1906) under the name, 'Cotton Stem Weevil' and it was apparently at that time not identified. The same author (1910) described it later under the name, *Phylaitis* sp. Fletcher (1913) stated that it does considerable damage to exotic cottons in Coimbatore district and later (1914) gave an account of its distribution, life-history, food plants, etc., in Madras State on the basis of information then available.

At the Second Entomological Meeting, held at Pusa in 1917, it was pointed out that at Coimbatore, in 1912-13, a large proportion of Cambodia cotton plants in the Government Agricultural Farm were attacked and about 25 per cent. of them succumbed, being broken off by wind. It was also stated that it is a specific pest of cotton, but is also found on *Abelmoschos esculentus* and *Hibiscus cannabinus*. Ayyar (1918) was the first to describe its habits and life-history in fairly great detail. Although the damage that the

pest is capable of causing was recognized early, Ballard (1923) strangely enough stated that it cannot be considered as one of the more important pests of cotton in India, except under exceptional circumstances.

The distribution of *P. affinis* in India is not very wide. Apart from Madras, it occurs in Andhra, Mysore, Bihar, Kerala, Orissa, Rajasthan, Uttar Pradesh, Gujarat and Assam. Outside India, it has been recorded in Burma (Shumsher Singh, 1944), Thailand (Krishna Ayyar, 1943) and the Philippines (Hargreaves, 1948). Except in Madras, it does not appear to be an important pest in India.

Krishna Ayyar and Margabandhu (1941) have studied the biology of *P. affinis* under controlled physical conditions. The emergence of adults continues up to a maximum of over two months. The proportion of females is found to be always slightly in excess of males. The adult generally feeds on the bark of the plant. Copulation commences immediately after emergence from the stems. Mating activity is seen at its maximum during mid-day when bright sunshine prevails. Copulation takes place at frequent intervals.

The egg is variable in shape from globular to oval or cylindrical depending upon the pressure exerted during oviposition. It is uniformly smooth, with no external sculpturing. The length averages 0.4 mm. and width 0.29 mm. Eggs are buried in the bast fibres of the bark. They are generally deposited in the region of the nodes which are tender, soft and succulent. Just before depositing the egg, the adult female beetle thrusts her snout into the bark and gnaws into it. After scooping out the chamber, the adult inserts the tip of the abdomen and deposits the egg. The chamber is then sealed with a mixture of gummy exudation.

The number of eggs laid per adult female averages 50. Maximum number recorded is 121 eggs per female. Egg-laying period varies from 60-80 days. The eggs hatch usually in 6-10 days.

The grubs are slightly curved, creamy white, with a distinct head. The larval period ranges from 35-57 days.

Pupation takes place in the stem in a specially prepared chamber and before turning into the pupa in this chamber, the grub constructs a passage through the stem to the outside leaving only the bark intact. The pupa is white in colour at first, but becomes brown before the emergence of the adult.

In Madras State, three complete generations are observed from October to April. From April onwards the generations overlap, but still two supplementary generations could be traced till the complete removal of crop by August. The incidence is noted to increase from an initial incidence of about 5 per cent. to as much as 95-100 per cent. in June. Table 43 gives the incidence of *P. affinis* during 1940-41 cotton crop in Madras.

Studies conducted by Krishna Ayyar (1942) show that the first generation roughly covers the period October-November. The second is not clearly defined, but occupies a period up to the middle of February. The third brood

commences somewhere in the last week of February and extends far into April. Between April and the end of August, two more supplementary broods, as stated already, could be feebly traced.

TABLE 43. INCIDENCE OF *Pempheres affinis* Fst. IN MADRAS

Month		Percentage incidence	Live stages for 100 plants	Percentage parasitism
October	1940	2·63	2·63	
November	"	47·32	50·53	
December	"	63·77	57·00	
January	1941	84·26	97·71	0·30
February	"	99·20	120·20	1·17
March	"	100·00	30·00	
April	"	100·00	54·70	
May	"	100·00	68·40	0·60
June	"	100·00	62·30	

Oviposition by the first brood probably commences somewhere in October. Early part of November reveals the presence of medium-sized grubs, a portion of which reach maturity towards the close of the month.

The ecological studies of *P. affinis* specially the influence of temperature and humidity on the weevil, by Krishna Ayyar (1941), has revealed some significant facts. Each phase of the weevil's life has distinct and differential requirements. The adults are unable to withstand high temperatures for considerable periods. For maximum functional activity and longevity, a temperature range of 90° to 98° F., associated with relative humidity of 60-80 per cent. is found to be the optimum. The duration of life is much affected by food. Mere supply of water does not seem to have any beneficial effect on its life duration or reproductive power. An exclusive carbohydrate diet produces a remarkable increase in duration of life. Addition of small amounts of protein is found to be conducive not only towards the longevity of the weevil but also towards fecundity.

Under a scheme financed by the Indian Central Cotton Committee, Dharmarajulu (1935) made a study of the nature of resistance in cotton plants to stem weevil. His observations showed that the resistance of Cambodia cotton to attack by *Pempheres* takes two forms, the production of a gall and the exudation of gum. He has given an account of the histology of these processes. The gall development took place in definite stages, the earlier ones following the general line of wound repair. The production of gum was directly dependent on the proliferation of tissue. The parenchyma of the cells disintegrated and flooded the gallery with the gum.

Alternate Host Plants. The weevil is found to breed on the following wild and cultivated plants:

Triumfetta rhomboidea
Corchorus olitorius

Corchorus trilocularis
Corchorus acutangulus

<i>Sida acuta</i>	<i>Abelmoschos esculentus</i>
<i>Sida cordifolia</i>	<i>Hibiscus cannabinus</i>
<i>Sida spinosa</i>	<i>Hibiscus surattensis</i>
<i>Sida glutinosa</i>	<i>Melochia coschorifolia</i>
<i>Sida rhombifolia</i>	<i>Abutilon indicum</i>
<i>Sida rhomboidea</i>	<i>Abutilon hirtum</i>
<i>Malvastrum coromandelianum</i>	<i>Abutilon glaucum</i>
<i>Hibiscus vitifolius</i>	<i>Thespesia</i> spp.
<i>Hibiscus ficulaeus</i>	<i>Urana lobata</i>

Of the above, *Triumfetta rhomboidea* Jacq. (Tiliaceae) is the most important alternate host plant. It is a common herbaceous shrub widely distributed in India. According to Krishna Ayyar (1940b), the weevil has developed such a high degree of preference for it that only a negligible fraction migrates directly from it to cotton, and an intermediate food plant is necessary before an influx into cotton fields takes place. The commonest of these plants are *M. coromandelianum* and *C. olitorius*.

Table 44 gives the percentage of incidence on different species of alternate hosts of *P. affinis* recorded in Madras during 1941-42 and shows the importance of *T. rhomboidea*.

TABLE 44. PERCENTAGE OF INCIDENCE ON DIFFERENT SPECIES OF ALTERNATE HOSTS

Alternate host plant	Percentage incidence of <i>P. affinis</i>
<i>Triumfetta rhomboidea</i>	70.2
<i>Hibiscus ficulens</i>	25.0
<i>Hibiscus vitifolius</i>	12.5
<i>Sida acuta</i>	4.4
<i>Malvastrum coromandelianum</i>	2.3

According to Ballard (1923) some strains of Cambodia cotton are less liable to attack in their early stages than others and among indigenous varieties, *Gossypium indicum* is much less affected than *G. herbaceum*. Krishna Ayyar (1940a, b) discusses the behaviour of *P. affinis* in different hosts especially in cotton and *T. rhomboidea*. The two preferred hosts are so markedly different that they present two distinct types of environmental conditions.

Although the factors affecting the abundance of the weevil are not understood, Krishna Ayyar (1943) considers that its distribution and incidence are closely connected with the presence of the preferred food plants. In the humid West Coast of Madras State (pre-reorganization), moisture, which is necessary for the development of the eggs and young larvae, but detrimental to the later larval and pupal stages, the adults and oviposition, is probably of importance, while in the southern and central districts, where cotton has only recently been introduced as a crop and occurs only in small patches, the weevil has not yet become adapted to it. Moreover, drought and high

temperatures during the summer, destroy the wild food plants except in favourable situation, thereby interrupting facilities for continuous breeding.

Natural Enemies. *Pemphres affinis* carries a rich fauna of natural parasites. There is differential parasitic fauna of *P. affinis* when it occurs on different host plants (Krishna Ayyar, 1941, 1943). The parasites recorded on *P. affinis* in association with cotton are:

<i>Euderus pempheriphila</i> Ayyar & Mani	}	Chalcididae
<i>Aplastomorpha calandrae</i> How.		
<i>E. pelmus urozonus</i> Dalm.		
<i>E. pelmella pedatoria</i> Ferr.		
<i>E. pelmus</i> sp.	}	Braconidae
<i>Spathius critolaus</i> Nixon		
<i>Microbracon</i> sp.		
<i>Rhaconotus</i> sp.		

Pyemotes (*Pediculoides*) *ventricosus* Newport—Acarina predator

The parasites recorded in association with alternate host plants which have been studied by Krishna Ayyar (1940) are:

<i>Entedon pempheridis</i> Ferr.	}	Chalcididae
<i>Dinarmus coimbatorensis</i> Ferr.		
(Syn. <i>Dinarmus santeri</i> Masi)		
<i>Bruchocida orientalis</i> Crawf.		
<i>Aplastomorpha calandrae</i> How.	}	Braconidae
<i>E. derus pempheriphila</i> Ayyar & Mani		
<i>E. pelmus urozonus</i> Dalm.		
<i>E. ryotoma</i> sp.		
<i>Aximopsis</i> sp.	}	Braconidae
<i>Spathius critolaus</i> Nixon		
<i>Spathius labadus</i> Nixon		
<i>Rhaconotus cleantes</i> Nixon		
<i>Rhaconotus menippus</i> Nixon	}	
<i>Geomermis indica</i> Steiner (Nematode parasite)		

All parasites are larval without exception and also primary in character. Except *Entedon pempheridis*, the rest are all ecto-parasites and select only covered hosts as differentiated from those living openly or exposed.

The extent of natural parasitism of *P. affinis* in the cotton fields is comparatively low and on the basis of incidence none of the parasites can be considered as efficient. In the first generation period of the pest (November-December) the percentage is very insignificant; maximum being less than one per cent. With the second generation, the parasitism is more pronounced and the percentage rises in keeping with the increase in host density.

Brief notes on the important parasites of *P. affinis* are given below:

Eulerus pempheriphila Ayyar & Mani (*Eulophidae*): This is a dark small-sized chalcid with a tiny ovipositor, attacking medium-sized grubs. It is the

most numerous amongst the weevil parasites collected from cotton fields. More than a single egg is laid but only one parasite grub attains maturity. The larva feeds on the host reducing it to an empty case. The total life cycle occupies 12-18 days. The adult is not a strong flier and also difficult to breed in captivity. It is hyper-parasitised by *Eupelmella pedatoria* Ferr. in the full-grown larval and pupal stages.

Aplastomorpha calandrae How. (*Pteromalidae*): This species is another important larval parasite of *P. affinis*. The adult is an active insect and is capable of attacking all the larval instars. It can be easily bred in captivity. Male progeny results when it reproduces parthenogenetically. The total life cycle occupies 10-17 days. The average longevity of the adult is 28 days.

Eupelmella pedatoria Ferr. (*Eupelmidae*): This is another ectophagus larval parasite of the weevil, but occurs only in small numbers. Males are unknown in the species and reproduction is always by thelytokous parthenogenesis. The total life cycle occupies 17-24 days. The maximum adult longevity is 47 days. The parasite also functions as an occasional hyper-parasite on *Euderus pempheriphila*.

Eupelmus urozonus Dalm. (*Eupelmidae*): This is only an occasional parasite of *P. affinis*. It is also a primary ectophagous parasite attacking full-grown grubs. The total life cycle occupies 14-17 days.

Spathius critolaus Nixon (*Braconidae*): A comprehensive account of this parasite has been given by Krishna Ayyar (1940c). It is one of the most important parasites occurring during the first generation of the pest. It is comparatively more efficient because of its ability to parasitise stages lodged deep in the stem. It paralyses more stages than actually oviposited upon. Other hosts on which *Spathius* is able to parasitise are *Sinoxylon sudanicum* in cotton, *Hypolixus truncatulus* in *Amaranthus* and *Sphenoptera araidis* in *Sesbania*.

The total life cycle occupies a period of 12-27 days according to season. The maximum adult longevity is found to be nearly 5½ months on sugar solution and nectar of cotton flowers.

It occurs during October-March in seasonal crops and from July-September in off-season crops in Coimbatore. In Ramnad district it has been found during September-December. It can be reared in the laboratory and outdoor cages in all seasons throughout the year on important alternate hosts. Given an abundance of host material, the species can be multiplied in considerable proportions.

Krishna Ayyar and Narayanaswami (1940) have made observations on the biology of *Spathius vulnificus* Wlk., a species closely allied to *S. critolaus* and observe that its potentialities in the control of *P. affinis* are very high.

Krishna Ayyar (1942) succeeded in the mass breeding of *Spathius critolaus* on *Hypolixus truncatulus* inside the laboratory and on *Sinoxylon sudanicum* in large outdoor cages. Preliminary releases were also made in selected cotton fields and the results obtained were encouraging. As stated already, the other



Fig. 37. Stem Borer (*Sphenoptera gossypii*, Cotes) 1. Boring Larva in Plant Stem. 2 and 3. Pupa and Adult

allied species *Spathius vulnificus* introduced from North India are also amenable to rearing in the laboratory.

Krishna Ayyar (1940b) mentions that ants of the genera *Tetraponera* (*Simia*) and *Monomorium* were predacious on the larvae and pre-pupae in tunnels in *Triumfetta rhomboidea*.

Nangpal (1948) mentions an unidentified fungus attacking all stages of *P. affinis* except the egg.

Control Measures. The only feasible method of control of *P. affinis* appears to be the rigorous application of some measure by which the pest could be starved out of its natural food. The application of Pests and Diseases Act, whereby all cotton crop would be removed by about a month before the sowing of the succeeding crop, is said to have been able to keep *P. affinis* in check in Madras. Ayyar (1932) recommends systematic removal of affected plants in early stage. Dharmarajulu, *et al.* (1934) state that field trials with earthing the plants up to cotyledonary node, thus covering the non-hairy parts and leaving above ground only the hairy ones, gave some promise of control. Close spacing also appeared promising. As adults, pupae and larvae soon died when the plants were dried immediately, sun-drying would prevent emergence from the stalks. By shortening the growing period of cotton so as to enable early harvests to be gathered, a long close season could be observed which might starve out the weevil. Maheswariah and Puttarudriah (1956) state that earthing-up along the rows of the seedlings at least twice in the early part of the season, controls the pest. No measures of control with chemicals are known, but trials are said to be in progress in Madras State.

In view of the difficulties in controlling the pest, a more sustained effort to control it biologically should be attempted. A very careful search for its natural enemies in Burma, Thailand and the Philippines is likely to yield good results. If such of the natural enemies which do not occur in India are introduced from these countries, there would be a good chance of controlling the pest.

COTTON STEM BORER, *Sphenoptera gossypii* Cotes

This buprestid borer is a minor pest of cotton and is widely distributed in India. The grubs of the beetle bore into the stem of the cotton plant which ultimately withers and dies. Apart from cotton it is also found attacking *Abelmoschos esculentus* (Fig. 37).

The adult female lays eggs singly on the bark generally about midway between the base and the crown of the stem. The eggs are small, greenish, elliptical and flattened. The grubs are white with the thorax greatly swollen. When full-grown they measure about an inch in length. The pupae are white at first, but become dark before emergence of the adult.

The natural enemies of *S. gossypii* include *Trichogramma* sp., and *Ooencyrtus* sp., on eggs; and *Vipio* sp., *Horminae* sp., *Glyptomorpha* ~~sm~~ *meen*us Cam., *Neocatalacous*

indicus R. & M. and *N. sphenoapterae* Ferr. on grubs. Thompson (1943) also lists the pupal parasite, *Xanthopimpla punctata* F. as parasitizing this species in India. He also lists *Glyptomorpha* sp., *Glyptomorpha smeenus* Cam., and *Vipio smeenus* Cam., as parasitizing *Sphenoaptera* sp. in India.

Ayyar (1932) advocates the destruction of first attacked plants and the collection of beetles when found in the fields. Maheswariah and Puttarudriah (1956) recommend pruning the twigs showing wilting and destroying them.

COTTON JASSID, *Empoasca devastans* Dist.

Empoasca devastans is economically the most important of about two dozen species of *Empoasca* known in India. It has been recorded in all the cotton growing States. There are no estimates of the actual loss caused by it. Afzal Husain (1937) mentions that *E. devastans*, more than any other insect, has been a nightmare for the cotton breeders in the Punjab. Lal (1941) mentions the failure of cotton over large areas in 1913 in the Punjab due to *E. devastans*. In Madras, it is one of the three or four major pests of cotton. The extensive work done so far in the country to breed *Empoasca*-resistant strains of cotton amply proves the importance of the above insect pest in affecting the yields of cotton. Balasubramanyan and Iyengar (1950) report that most of the American cottons grown in Tungabhadra Project area suffer from the ravages of this pest. This pest came into prominence about 40 years back in the Punjab with the introduction of the American cottons. Husain (1937) mentions a serious outbreak that occurred during 1930 in the Punjab. Life and seasonal histories of the pest have been worked out by Husain (*loc. cit.*) and Husain and Lal (1940) in the Punjab (Fig. 38).

Eggs are laid inside the leaf veins usually in the spongy parenchymatous layer between the vascular bundles and the epidermis. The average number of eggs laid by a female jassid is about 15, the maximum number recorded being about 29. The incubation period varies from 4-11 days. The nymphs moult five times. The nymphal stage is about 7 days in autumn and 21 days in winter. According to Husain and Lal (1940) unmated adults of *E. devastans* supplied with fresh food can live up to a period of three months or longer, but mated examples did not live longer than 5 weeks in summer and 7 weeks in winter. Copulation takes place either in the early morning or late in the evening. The two sexes attach themselves together end to end with their heads pointing out in the opposite directions. The adult jassids exhibit seasonal variations in colour; the winter broods being markedly reddish while the summer broods are greenish yellow. Nangpal (1948) states that mating takes place 2-16 days after emergence and oviposition occurs 2-7 days after copulation.

About 11 generations have been observed in a year in the Punjab, the duration of each varying from 15-46 days, but there is considerable overlapping. The insect is not known to hibernate and if conditions are favourable rapid

multiplication takes place. The adults being generally long-lived can tide over adverse climatic conditions.



Fig. 38. Jassid (*Empoasca devastans* Dist.)

The injury caused by *E. devastans* to cotton and other host plants is through sucking which results in curling up of the leaves followed by necrosis. The attacked leaves turn red or brown in colour.

Afzal, Rajaraman and Abbas (1943) studied the effect of *E. devastans* infestation on the development and fibre properties of the cotton plant. In cage tests conducted, they maintained populations of 200-300 nymphs per cage on plants of resistant and susceptible varieties. There was a significant reduction in plant growth, number of flowers, number of bolls and weight of seed cotton in the susceptible variety compared with the uninfested controls of the same variety. The various qualities of the cotton lint were also affected adversely.

The incidence of *E. devastans* in relation to agronomic practices has shown that cotton planted early is less injured than the crop sown late in the season as the latter carries a greater jassid population. Observations made in India indicate that the jassid attack increases with the increase in irrigation. Phadnis (1954) in Bombay reported that excessive rainfall is conducive to the development of jassids. Wide fluctuations in the annual incidence and progressive decrease in insect population after particular months have been noted in various places, the causes of which still remain to be investigated. In the

Punjab, the incidence is correlated with high rainfall, while droughty conditions are known to favour jassid attack in the Deccan and South India.

Hargreaves (1934) mentions that the jassids, *Empoasca fascialis* Jac., in Africa are usually most prevalent on cotton grown on poor soil with an inadequate supply of water during dry weather, the effect of which on the plant may have been erroneously ascribed to the insects. This author attributes the fact that certain varieties apparently suffer less from infestation by jassids, due to their greater adaptability to a particular environment and their resistance to drought. He further states that the cultivation of jassid-susceptible cottons (possibly of greater value) in somewhat drier areas might perhaps be rendered practicable by an increase in humus or by cultural conservation of moisture.

According to Parnell, as stated by Hargreaves, at Barberton (Transvaal), the worst attacks by the jassids occurred after heavy rains; infestation also appeared to be connected with poor or water-logged soil. In his experience, resistance did not appear to be due to better adaptation to environment, as strains of cotton introduced from other countries grew well and were not affected by drought, though they invariably succumbed to the jassid. Their only defect was a lack of dense hairs on the leaves, which, on other varieties, appear to interfere with the feeding of the nymphs. During experimental work, a close connection was observed between hairiness of the foliage and resistance to infestation. Moderately susceptible varieties appear to be attacked when the crop begins to ripen, but very susceptible ones are infested earlier. The insects do not appear to be attracted to plants showing vigorous vegetative growth or to breed on them. Plants carrying a very small crop are markedly less susceptible.

Not much work has been done on *E. devastans*, although Lal had, as early as 1941, indicated the future lines of work necessary in this regard. Detailed investigations on the relationship between climatic factors and the incidence of *E. devastans* have to be undertaken. In the Punjab, the incidence is correlated with high rainfall while droughty conditions are known to favour jassid attack in the Deccan and South. The population of the jassid is more per plant in the wide-spaced plots. Balasubramanyan and Iyengar (1950) record that manured plots show greater population of jassids per leaf than unmanured plots. Appa Rao, Janardhan Raju and Priyavratna Rao (1959) made observations on the influence of manuring on incidence of jassids. They found that the nymphal populations were greater in the manured plots as had been found by other workers. The authors state that plots manured with ammonium sulphate appeared to attract more jassids than those manured with groundnut cake.

In the Punjab and Sind, *E. devastans* is known to be most serious during the months of July-August. But in central India where the American cotton is mainly grown as a rainfed crop, the attack occurs when the crop is only a

few weeks old. A late-sown rainfed crop is attacked immediately after germination with the result that a large number of plants are killed outright. In Madras, it is observed in the field from October onwards and reaches a peak in December-January.

The habits of *E. devastans* have been studied in detail by Husain and Lal (1940). The first and second instars prefer to feed near the bases of the leaf veins. During the later instars they get distributed all over the leaf, but feed chiefly on the under-surface. Ordinarily they do not move about much, but become very active when disturbed. Nymphs of the last two instars are able to jump a distance of about eight inches. Usually cotton in the pre-flowering stage is most susceptible to attack. Nymphs as well as adults cause injury to the plants mainly by injecting toxic saliva into the tissues. There is no evidence however, of any virus being transmitted by the jassid.

Alternate Host Plants. *Empoasca devastans* is known to breed, apart from cotton, on castor (*Ricinus communis*), hollyhock (*Althaea rosea*), brinjal (*Solanum melongena*), potato (*Solanum tuberosum*), *Hibiscus cannabinus*, bhendi (*Abelmoschos esculentus*), *H. vitifolius*, *Helianthus annuus* (sunflower), and cucurbits. Husain and Lal (1940) state that *Abelmoschos esculentus* and *Hibiscus vitifolius* are the most favoured alternate hosts.

Natural Enemies. No effective natural parasites have so far been recorded on *E. devastans*. Nasir (1947) has observed *Chrysopa cymbele* Banks preying in large numbers on the jassid in the Punjab and has described two new colour varieties *fasciata* and *afasciata* of the *Chrysopa*. Some species of spiders like *Distina albida* and ants like *Camponotus* are observed feeding on the jassid, but are not effective as a control (Nangpal, 1948).

Control Measures. These are detailed below:

Breeding Resistant Varieties: Earlier work done in India to control *E. devastans* has been mostly centred towards evolving resistant varieties, as the direct method of control with insecticides was observed not to be a practical proposition in view of the eggs being laid in the leaf veins. Both in the Punjab and Madras, a large amount of work has been carried out on this aspect of the problem. In the course of study it was observed that the *desi* varieties (*Gossypium arboreum*) are highly resistant to jassid attack and that *E. devastans* exhibits considerable discrimination in its attack on different varieties of cotton. Husain and Lal (1940) opined that the following two conditions might be responsible for the differential behaviour of *E. devastans* towards the varieties, namely: (i) inability of the females to oviposit on a host; and (ii) inability of the nymphs to feed and develop on it. As a result of field experiments they conclude that nymphs of all stages of *E. devastans* could feed on both the susceptible and resistant varieties but there is marked reduction in egg-laying (or possibly hatching of nymphs) on resistant varieties. Sikka and Singh (1953) have studied genetical aspects of jassid resistance on three

acclimatized Punjab-American cottons, viz., 124F, 238F and 199F and four imported Upland American varieties, viz., Tide Water, Webber, Wild's Strain and Missdel. These varieties were classified into four distinct categories, viz: (a) highly susceptible (grade 4); (b) slightly resistant (grade 3); (c) mediumly resistant (grade 2); and (d) highly resistant (grade 1).

The following crosses were studied to determine the nature of inheritance of jassid resistance with a view to determine the genetic constitution of the parental varieties belonging to each category:

124F x Tide Water	Grade 3 x Grade 4
124F x Webber	Grade 3 x Grade 4
124F x Missdel	Grade 3 x Grade 2
124F x Wild's strain	Grade 3 x Grade 2
199F x Tide Water	Grade 1 x Grade 4
199F x Webber	Grade 1 x Grade 4
238F x Tide Water	Grade 1 x Grade 4
238F x Webber	Grade 1 x Grade 4
199F x Missdel	Grade 1 x Grade 2
199F x Wild's Strain	Grade 1 x Grade 2
238F x Missdel	Grade 1 x Grade 2
238F x Wild's Strain	Grade 1 x Grade 2

It has been found that by the crossing of 124F x Webber and 124F x Tide Water, the F_2 generation segregated in the ratio of 3 resistant: 1 susceptible. In these crosses Webber and Tide Water parents are susceptible to jassids while 124F is slightly resistant. By further crossing of 124F either with Missdel or Wild's Strain, a highly resistant F_1 was obtained, indicating that factors for resistance present in 124F are different from the factors present in Missdel and Wild's Strain. If these factors are brought together, the F_1 is more resistant than the resistant parent.

Some of the likely factors responsible for producing immunity in the cotton plant from the attack of *E. devastans* have been studied. Hairiness of the cotton leaf was supposed to be one of the factors contributing to resistance, but was not found to be a very important factor later. Lal (1937) states that though hairiness of the leaf is thought to be a governing factor of anti-jassid resistance, it was found that the most hairy American variety which also had the greatest average hair length, was not the most resistant. It was also shown experimentally in Pakistan by Afzal and Ghanj (1953) that on a very hairy strain of cotton, the population of nymphs was no greater on leaves that had been shaved than those from which the hairs had not been removed, and the conclusion was that hairiness was not the prime factor for resistance. On the other hand, work carried out by Parnell, *et al.* (1941) has shown a close and constant relation between degree of hairiness of the under-surface of the leaf and degree of resistance to the jassid.

The toughness of the leaf vein is also believed to be closely associated with jassid resistance. Iyengar (1959) has, therefore, devised an instrument for the determination of the toughness of the veins of cotton leaves.

The reaction of the cell sap (pH value) from the leaves and the thickness of the cuticle were also not found to be associated with resistance to leaf hopper.

The whole question of jassid resistance has been admirably summarised by Pearson (1958). One can only conclude that a more critical re-examination of all factors is necessary.

The varieties mentioned as showing resistance to *E. devastans* are 4F, L.S.S. and 289F/43 in the Punjab (Afzal and Abbas, 1944); Co.2, Mysore-American 2, M.U.8 A in Indore (Ramiah, *et al.*, 1946); Cultures 1821 and 2196 in Tungabhadra Project area of Mysore State (Jagannatha Rao, *et al.*, 1952); and M.A.2 in Ceded districts of Andhra (Balasubramanyan and Iyengar, 1950).

Joshi and Priyavratna Rao (1959) have discussed the problem of breeding jassid-resistant varieties. In view of the superior quality of *Gossypium hirsutum*, hybridisation work to evolve varieties which are jassid-resistant is necessary. The two characters, that is, hairiness of leaves and toughness of leaf veins, should be bred into the *hirsutum*, retaining desirable characters, such as, yield, fibre quality, earliness and resistance to other pests like aphids, thrips, bollworms, and diseases.

Chemical Control: Cherian and Kylasam (1938) state that contact sprays with nicotine have given very good results against adults and nymphs, especially the latter. Lime sulphur and bordeaux mixture have practically no effect on the pest.

Sardar Singh, Sidhu and Sidhu (1959) report that spraying the infested crop with a mixture containing 0.1 per cent. DDT and 0.1 per cent. BHC suspensions or 0.02 per cent. endrin emulsion at 50 to 100 gallons of spray material per acre at two-week intervals effectively controlled the pest. The increase in yield of seed cotton obtained was so great that it more than compensated for the cost of the insecticides. Although phosphatic insecticides gave high initial mortality, they were unable to keep the pest incidence suppressed for any length of time, owing to their low residual effects. Srivastava (1959) advocates dusting the crop with 5 per cent. BHC or spraying with 0.25 per cent. DDT suspension.

Patel, *et al.* (1957) have made field trials for a comparative study of the control obtained by using nicotine sulphate, DDD, BHC, DDT, toxaphene, BHC plus DDT, dieldrin, endrin and ethyl parathion sprays. Some of them were also tried by them after mixing with a mixture of lindane, DDD and sulphur and chlordane plus sulphur. They found DDD, toxaphene and DDT as 0.2 per cent w/d were equal in toxicity and were superior to nicotine sulphate (1:800). Dusts consisting of 5 per cent. DDT plus 3 per cent. lindane plus 40 per cent. sulphur and 5 per cent. DDT and sulphur (1:1) mixture, were

equal in their toxicity and both give significantly higher percentage decline than 5 per cent. DDD and sulphur (1:1) and 5 per cent. chlordane and sulphur (1:1). Two ounces of endrin per acre and 0.01 and 0.02 per cent. ethyl parathion are equal in toxicity to 0.02 per cent. (w/d) DDT plus sulphur, and are cheaper than the latter. Patel, *et al.* (1956) warn that sulphur and DDT mixture should not be used for Indian or Asiatic cottons, as sulphur scorches these varieties severely. On Asiatic cottons, however, jassid infestation is less due to their relative resistance to jassid attack. If, however, infestation appears, 5 per cent. DDT alone should be used on such varieties. The DDT and sulphur mixture is only safe on the American varieties of cotton, which are more prone to jassid infestation.

In Madras (Anon., 1954) a cotton dust having DDT 5 per cent., BHC 24 per cent. and sulphur 20 per cent. is said to have been effective against jassids when dusted at the rate of 12 lb. per acre. The DDT 3 per cent. dust has been found to be quite effective against cotton jassids on Laxmi cotton in Hyderabad at the rate of 15-20 lb. per acre. Kulkarni and Katgihallimath (1955) have conducted trials with DDT and BHC and found that both the insecticides are very effective against *E. devastans* whether in dust or in spray form. If dusting treatments are effective, they would go a long way in the successful protection of cotton against jassids, especially as water is a limiting factor in spraying operations in most of the dry cotton growing tracts of the country.

In Mysore, Maheswariah and Puttarudriah (1956) recommend spraying either with tobacco decoction (1 lb. tobacco in 8 gallons of water + 1/8 lb. soap) or Geigy's DDT—Guesoral 550 (1 lb. in 16 gallons of water).

Other Species of *Empoasca* Found on Cotton. Investigations on other species of *Empoasca* attacking cotton were carried out at Lyallpur in the Punjab by Abbas and Afzal (1945). Samples of *E. devastans* collected almost always included *E. kerri* var. *motti* Pruthi, *E. minor* Pruthi and *E. punjabensis* Pruthi, but were not found to cause any injury to cotton.

**COTTON WHITE-FLY, *Bemisia tabaci* Genn.,
(Syn. *B. gossypiperda* Misra & Lamba)**

Bemisia tabaci is found on cotton in the Punjab, Uttar Pradesh, Bombay, Bihar and Delhi, but is a major pest only in the Punjab. It has not been recorded as a pest in other cotton growing States of the Union. Usman and Puttarudriah (1955) have recorded it on sugarcane in Mysore State. Apart from the Indian sub-continent it is known to occur in various parts of Africa where it is reported to act as a virus vector of 'leaf-curl' disease. Its life-history and bionomics have been studied by Misra and Lamba (1929), Husain (1931), Thomas (1932), Husain and Trehan (1933), and Trehan (1944). Trehan (1944) has also made a study of the distribution of the pest in the Punjab. He states that high temperatures and low rainfall were found to favour rapid

multiplication and that infestation was highest at low altitudes and on crops that received little irrigation.

The adult is a small insect having an yellow body which is lightly dusted with waxy powder. It sucks sap from the leaves and drains the plant food. The honeydew which it exudes falls on the leaves and serves as a medium for the growth of black moulds which interfere in photosynthesis. The eggs are stalked, sub-elliptical in shape and light yellow, when freshly laid, and change to dark brown subsequently. Eggs are laid singly on the lower surface of the leaves. The female can lay up to a maximum of about 120 eggs with an average of 28-43 eggs. The incubation period varies according to the season, being largest during winter (33 days) and shortest during April-September (3-5 days).

Nymphal stage is completed in 9-14 days during April-September and 17-81 days in winter. The first instar nymph is oval, light yellow, margin of body with 16 pairs of bristles and legs functional. The nymph of the second instar is oval, depressed, pale greenish yellow, legs degenerate, without joints. The third instar is akin to second instar. The pupal stage occupies 2-8 days. The body of the pupa is slightly convex, deep yellow in colour. The complete life cycle lasts for 14-107 days.

The behaviour of the adult has been studied in the Punjab. *Bemisia tabaci* shows the greatest attraction to yellow green coloured light, and next highest for yellow, while the least number of them are attracted to bright red, orange, red, dark green and purple coloured lights.

The insect has about 12 broods in an year, but the generations overlap, and, therefore, all stages of the pest are found throughout the year. It breeds practically all the year round, often parthenogenetically, producing only males.

The seasonal activities of the pest have been studied in detail by Husain, Trehan and Verma (1936). *Bemisia tabaci* is polyphagous and its range of host plants includes about 14 species, both cultivated and wild, belonging to 13 families. Usually *B. tabaci* undergoes three phases of migration during the course of a year.

1. During November, when the cotton crop is maturing the white-fly population declines and infestation is built up on such alternative host plants as rape, cauliflower, turnip and potato among the cultivated plants and *Sonchus* spp., *Euphorbia* spp., and *Convolvulus arvensis* among the commoner of the weeds. From December onwards the number of adults falls considerably, but the immature stages remain on these alternative hosts throughout the winter. The adults commence emerging from about the end of January and multiply once again on the winter host plants already named above.
2. By the end of March, the white-fly migrates to its spring hosts, namely, *Citrullus vulgaris*, *Cucumis sativus*, *Lagenaria vulgaris*, etc., where rapid

multiplication takes place. From April onwards ratoon cottons form the most important breeding centre.

3. The white-fly makes its appearance on new cotton early in May, soon after the crop has germinated, but the attack at this stage is extremely low as compared to the other host plants, but mainly on account of rapid multiplication of the pest, the intensity of attack increases enormously on the new cotton crop. The period of severe attack on cotton extends from June to August after which the infestation declines abruptly. Husain, Puri and Trehan (1936) have found this species infesting indigenous varieties of cotton more seriously, early in the season, and American types in July or August. They thought this behaviour as probably dependent on some difference in the cell sap of the tender and older leaves and to changes in the sap of the varieties during different parts of the year. The relative incidence of infestation corresponded with the trend of pH curve, indicating towards higher pH values.

Husain and Trehan (1942) have shown that the incidence of *B. tabaci* is generally lower in plots receiving a greater amount of irrigation water than in the crop which receives a restricted supply of water. Plants treated with nitrogenous manure showed comparatively lower infestation and the percentage of shed and defective bolls was lower than in plants manured with sodium nitrate and ammonium sulphate. Further experiments showed that the average attack was lowest on soil treated with ferrous sulphate at the rate of 820 lb. per acre. Further, the incidence of attack on the early-sown crop is comparatively higher up to September after which it becomes uniform on all the sowings. There is not much difference between the cotton sown on 1st May and 1st June, but the cotton sown later escapes the attack of the pest. The intensity of attack is slightly lower on manured plants.

The white-fly activity correlated with climatic conditions have shown that the attack is highest in areas of high temperature and scanty rainfall.

The attack of *B. tabaci* is found to be relatively low on plants grown in soils of slightly lower pH value as compared to those grown on more alkaline soils.

The economic status of this Aleurodid has been discussed at length by Husain (1931) and the nature and extent of damage caused by it has been dealt with in detail by Husain and Trehan (1942). The white-fly attack on cotton results in the lowering of the vitality of the plants. It is also a vector of the leaf curl disease. Investigations have shown that the infestation of a cotton plant by the white-fly is detrimental at all stages, viz., the growth period, the time of flowering and boll formation, and of lint and seed development. When the infestation is severe, the vegetative growth is checked and in most of the cases it is stopped. Boll formation becomes indirectly proportional to the intensity of attack, whereas shedding and 'bad opening' re-

main in direct proportion. A secondary effect of white-fly attack is the production of honeydew which in turn gives rise to sooty mould which interferes with photosynthesis. According to Thomas (1932), the loss caused by this pest in a year of general crop failure exceeds £5,000,000.

Natural Enemies. Husain and Trehan (1933) state that the third instar nymphs and pupae of *B. tabaci* are parasitized by chalcids which deposit their eggs within the body of their hosts, the parasites completing their life cycle in 6-7 days in August. The predators of *B. tabaci* include larvae of *Chrysopa* spp. and of a coccinellid beetle (*Brumus* sp.). According to Pearson (1958), *Eretmoceros diversiciliatus* Silv., *Prospaltella* sp. and *Encarsia* sp., parasitize *B. tabaci* in the Sudan. He thinks that *Eretmoceros* which parasitizes only late instar nymphs may be of some importance.

Bemisia tabaci does not show any varietal preference in infesting cotton as all varieties are severely attacked. The *desi* varieties, in general, are comparatively more infested during the growing period, i.e., till about the end of August, after which the attack may increase once again on the *desi* varieties towards the end of the season when they begin to sprout.

Control Measures. Clean cultivation and safe disposal of alternative hosts in the cotton off-season reduce the extent of white-fly attack. Proper manuring at the right time helps the plant to recover from the damage caused by the white-fly.

Insecticidal trials carried out in the undivided Punjab with rosin compound, fish-oil soap, tobacco decoction, kerosene oil emulsion and lime sulphur have shown that rosin compound is quite satisfactory against *B. tabaci*. Thomas (1932) states that rosin-soda spray gave best results. The details of economics of field spraying have been worked out by Husain, *et al.* (1939). Amongst the spraying machinery, cart-sprayers have been shown by them to be better and Hardie Power Sprayer with a 2 H.P. pump as most satisfactory. Spraying *desi* cotton in July and American cotton in August is effective in increasing the yield of cotton. The authors came to the conclusion that an increase in yield varying from 1 to 2·2 maunds per acre could result depending upon the variety and time of spraying.

In the Punjab, at present, spraying with 0·15 per cent. BHC at 100 gallons or 0·02 per cent. endrin is found to be effective and economical against *B. tabaci*. Sardar Singh, *et al.* (1959) have described the field control of the white-fly in the Punjab. Spraying at two weeks' interval with a mixture of 0·1 per cent. DDT and 0·1 per cent. BHC suspension or 0·02 per cent. endrin emulsion at 50-100 gallons per acre from July-September is generally recommended.

Other control measures suggested by Thomas (1932) are a light application of nitrogenous manure at the flowering stage (late August or early September); delaying the sowing of the crop until late May or early June in order

to escape the period of maximum infestation; and breeding resistant varieties. There appears to be good scope for the control of this pest using natural enemies imported from other countries where they are known to exist. Before this is done, a careful study of the indigenous natural enemies should be made.

COTTON APHID, *Aphis gossypii* Glover

Aphis gossypii has a wide distribution. It is considered as a minor pest, but in some seasons it does considerable damage. It is a polyphagous insect and its host plants include, apart from cotton, sannhemp (*Crotolaria juncea*), *Capsicum* sp., *Abelmoschos esculentus*, brinjal, *Amaranthus spinosus*, *Cassia* sp., *Argemone mexicana* and a number of other hosts (Plate XVI).

Aphis gossypii is a small, soft, greenish brown insect, found in colonies on tender portions of the plant. It sucks the plant sap with the result that the vitality of the plant is lowered, the leaves become curled up, the tender portions fade gradually and the whole plant becomes more or less blighted in the case of bad attack. Younger plants suffer more from aphid attack than older plants. The insect also produces honeydew on which sooty mould grows.

In South India, according to Ayyar (1932), Cambodia cotton suffers more from aphid attack than the indigenous varieties. Smooth-leaved varieties are more susceptible.

The sequence of *Aphis* incidence recorded at Delhi on different plants in an year is as follows: cotton—from September to February and sometimes up to April; potato—from December to March; *Capsicum* spp.—from September to April; hollyhock — from November to March; *kangi* — from December to April, *Abelmoschos esculentus* — from September to November; brinjal — from February to April; watermelon — from April to June; *tori* — from August to September; and sannhemp — from August to September.

Hargreaves (1934) states that dry conditions favour the rapid increase of *Aphis gossypii* Glov. on young plants, but rain causes an almost immediate reduction in its number, which may be continued further by an entomogenous fungus. The small development of the root system of the young plants may be responsible for their susceptibility. According to W. L. Ballo, as stated by Hargreaves, heavy infestation of a part of a field by *A. gossypii* at Giza (Egypt) was found to be connected with an unhealthy condition of the plants due to the presence of a layer of clay through which the roots penetrated with difficulty. Differences in the growth of the plants could be observed, as their roots reached layers of the soil of different composition.

Natural Enemies. A number of natural enemies have been reported on *Aphis gossypii*. Two birds, namely, brown willow warbler (*Phylloscopus tristis*) and Rufous fantail (*Cisticola cixsitans*) prey on the cotton aphid. Amongst the insect predators, the following have been recorded:

<i>Chilomenes sexmaculata</i> Fab.	}	Coccinellidae
<i>Coccinella septempunctata</i> Linn.		
<i>Scymnus</i> sp.		
<i>Coelophora bissellata</i> Mulsant		
<i>Nephus regularis</i> Soc. var. <i>nudipennis</i> Sic.		
<i>Pullus xeramphelinus</i> Mulsant		
<i>Pullus</i> sp. ? <i>quadrillum</i> (Mots.)		
<i>Pullus</i> sp. ? <i>guimeti</i> Mulsant	}	Chrysopidae
<i>Chrysopa</i> spp.		
<i>Hemerobius</i> sp.		Hemerobildae
<i>Syrphus confracter</i> Wied.	}	Syrphidae
<i>Sphaerophoria javana</i> Wied.		
<i>Ischiodon scutellaris</i> Fab.		
<i>Syrphus serarius</i> Wied.		
<i>Syrphus balteatus</i> De Grer	}	Ochthiphilidae
<i>Leucopis griseola</i> Fall.		
<i>Leucopis nigricornis</i> Egger		
<i>Triphleps tantilus</i> Motsch		Anthocoridae

Nangpal (1948) mentions that *Syrphus confracter* has proved very effective in Bihar. Pruthi and Bhatia (1938) have given a detailed account of *Leucopis griseola* and report that it is a very effective predator, the larvae feeding actively on young aphids. In nature the predators keep an effective check on *A. gossypii*. Apart from predators, *A. gossypii* nymphs are parasitized by an unidentified chalcid. Ballard (1921) has described the feeding habits of *Triphleps tantilus* Motsch, which he says is easily reared. Pearson (1958) has enumerated nearly 35 species of natural enemies of this pest in Africa. He also mentions about the fungus *Empusa frensii* Novak attacking the aphid in Uganda.

Control Measures. Ayyar (1932) advises the pruning of infested shoots and burning them in early stages and application of a contact insecticide like fish-oil soap, kerosene oil emulsion or tobacco decoction. In Madras it is reported that BHC 0.1 per cent. spray, BHC 5 per cent. or HETP 0.001 per cent. are equal in efficacy to tobacco decoction. In Madhya Pradesh dusting with 5 per cent. DDT or spraying with fish-oil rosin soap or nicotine sulphate is recommended (Gupta and Joshi 1955). In Assam, dusting with BHC 5 per cent. or spraying with nicotine sulphate, tobacco decoction or crude oil emulsion is advocated. In Andhra, spraying with either BHC 0.1 per cent. or parathion 0.025 per cent. is recommended (Thirumala Rao, *et al.*, 1954). Kulkarni and Katagihallimath (1955), however, state that DDT and BHC are not effective against *A. gossypii* and on the contrary, there would be a positive rise in the insect population. Patel, *et al.* (1956) recommend: (i) spraying with nicotine sulphate at the rate of 1 lb. in 80 gallons of water with 5 lb. of soap which is quite effective; (ii) spraying with pyrocolloid in

the proportion of one part in 1000 parts of water which also gives satisfactory results; and (iii) spraying with fish-oil rosin soap at the rate of 8 ounces in 4 gallons of water nearly 80 to 100 gallons of spray being required per acre in each case. The authors state that for control of aphids, DDT should be avoided, as it may not only kill them but may also lead to their increase. The BHC is somewhat effective, but the kill obtained is less than that with such compounds as nicotine sulphate and pyrocolloid.

RED COTTON BUG, *Dysdercus cingulatus* Fabr.

Red cotton bug is an important pest of cotton in Uttar Pradesh, Bihar, Madhya Pradesh, Bombay and Madras. Its morphology and biology have been studied by Pruthi (1921) and anatomy and bionomics by Hem Singh (1923). Sen (1924) gives brief biological notes on the pest, while Mehta (1930) has studied the influence of temperature and humidity on its bionomics. Srivastava and Bahadur (1958) have recently made observations on the life-history of the bug in Uttar Pradesh. Banerji and Basu (1955) state that it is a serious pest of cotton bolls in West Bengal. In Madras State an allied species, *Dysdercus olivaceus* Fabr., is also known to attack cotton. The nature of damage done to the crop consists of adults and nymphs sucking the sap from the green plant as well as bolls. In the former case the vitality of the plant is lowered while in the latter case, the bolls open badly and the quality of the lint is affected. Seeds are attacked and become unfit for either sowing or for oil extraction. In Burma, Rhind (1927) states that serious damage to cotton is caused by internal disease of unripe bolls which is the result of infestation by two species of *Nematospora*, a yellow or brown discolouration of the lint occurring first, followed by the rotting of the entire contents of the boll. He found the periodicity of the disease corresponding with the increase and decrease of *Dysdercus cingulatus*.

Hargreaves (1934) states that the damage due to the boll rot introduced by *Dysdercus* spp. is more serious during cooler and wet periods, though the bugs themselves are not necessarily more abundant.

The eggs are spherical, bright yellow in colour and are laid in a loose irregular mass. They hatch in about seven days. The nymphs pass through five instars. Nymphal period occupies 49-89 days.

Apart from cotton, *D. cingulatus*, is known to attack *Abelmoschos esculentus*, *Zea mays*, *Pennisetum typhoides*, *Hibiscus cannabinus*, *Solanum verbacifolium*, etc.

Among the parasites and predators, four species of birds are known to feed on this insect. The adults are parasitised by a tachinid fly. The reduvid bug (*Harpactor costalis* Rev.) is also observed as an effective predator.

Other species of *Dysdercus* like *D. suturellus* Schaef., and *D. ruficollis* L., have been reported on cotton in other countries.

Nangpal (1948) recommends sowing of *Abelmoschos esculentus* as a trap

crop as a control measure of *D. cingulatus*. In Assam and Madhya Pradesh dusting with 5 per cent. DDT or 10 per cent. BHC is recommended. Lal and Tiwary (1958) have made observations on the systemic action of organic phosphates on this bug. They have found that the percentage of mortality of adult bugs was greatest when systox at 0.05 per cent. concentration was used.

Maheswariah and Puttarudriah (1956), in Mysore State, have recommended the same measures as suggested for control of the pink bollworm.

Patel, *et al.* (1956) recommended the following control measures: (i) bolls are shaken in a tray containing a little kerosene oil added to water; and (ii) in case of heavy infestation, 5 per cent. BHC dust is used.

DUSKY COTTON BUG, *Oxycarenus laetus* Kirby

This lygaeid bug is widely distributed throughout India. The nymphs and adults suck juice from immature seeds which do not ripen and lose colour. They also stain the lint by getting crushed at the time of ginning. According to Misra (1921) this bug causes frequently more than 20 per cent. loss of the value of the crop. He has described its life-history also (Fig. 39).

The eggs are cigar-shaped when freshly laid, turn pale later on, and become pink before hatching. The eggs are 1.1 mm. long and 0.3 mm. broad. The life cycle occupies 36-50 days during the months of November-January.

Its alternate hosts include *Abelmoschos esculentus*, *Hibiscus sabdariffa*, *H. cannabinus*, *Abutilon indicum*, and *Thespesia* sp.

Nangpal (1948) recommended the plucking of infested bolls and destroying them. Gupta and Joshi (1956) advocate dusting with 5 per cent. DDT in Madhya Pradesh. Patel, *et al.* (1956) recommend the same control measures as given above for the red cotton bug. Maheswariah and Puttarudriah (1956) suggest the same control methods as those suggested for controlling the pink bollworm.

No parasite of any stage has been observed. Misra (1921) has observed the Anthocorid bug (*Triphleps tantilus* Motsch.) attacking the nymphs on cotton at Pusa. A large number of parasites and predators are known to attack *Dysdercus* spp. in Africa and these have been listed by Pearson (1958). In Uganda, the fungus, *Entomophthora sphaerosperma* is known to attack both adults and nymphs during wet weather. The introduction of these natural enemies might be of some benefit in those areas where the pest is of some importance in India.

MEALY BUGS, *Ferrisiana virgata* (Ckll.), and *Pseudococcus corymbatus* Green

Two species of mealy bugs are commonly found on cotton. They are *Ferrisiana virgata* (Ckll.) and *Pseudococcus corymbatus* Green. Both are minor

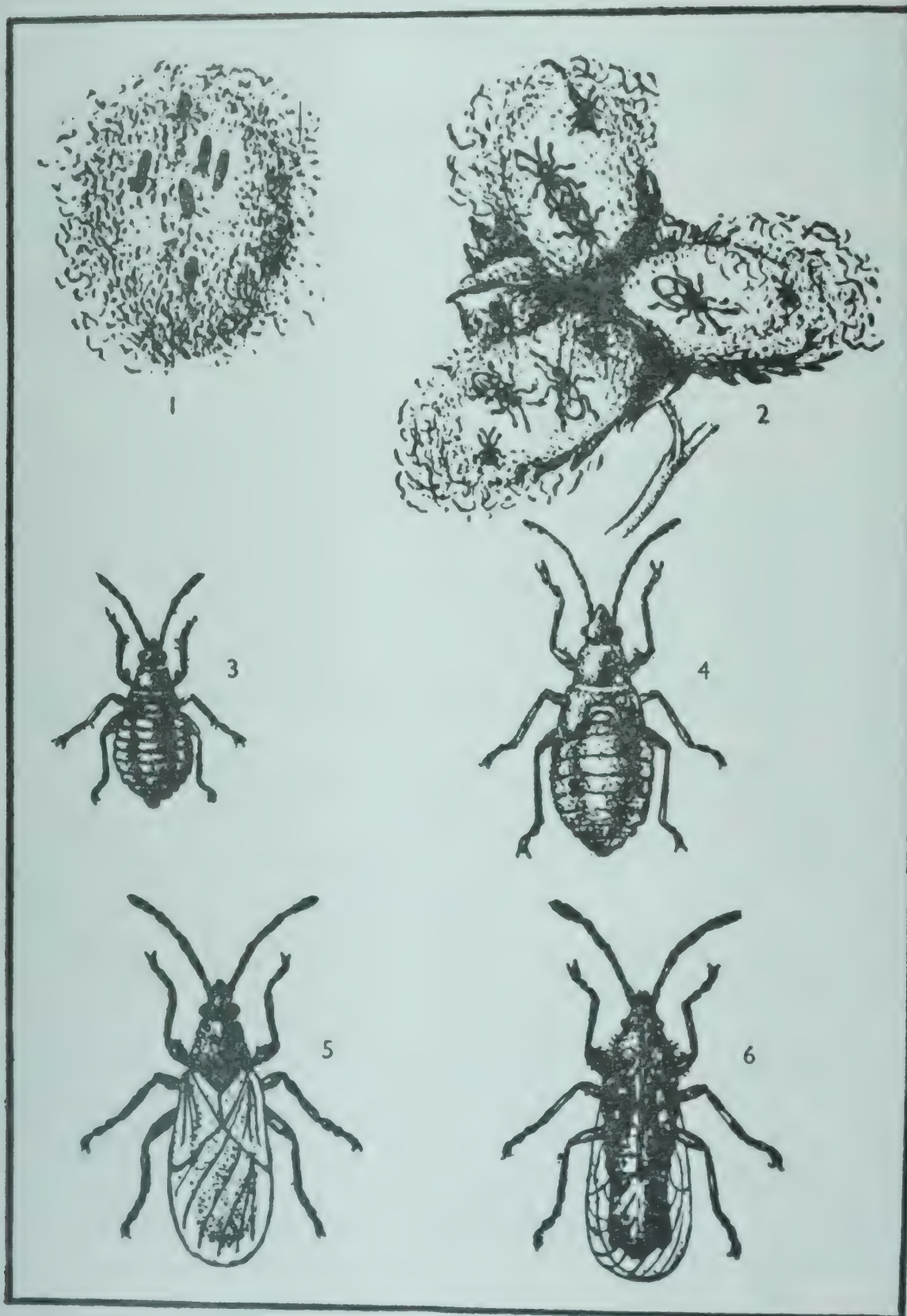


Fig. 39. Dusky Cotton Bug (*Oxycarenus laevis*, Kirby). 1 and 2, Nymphs and Adults in Boll. 3 to 6, Different Stages of Growth.

pests, the former being found in Bombay, Bihar and Madras, and the latter in the Punjab, Bihar and Madras. Another species, *Phenacoccus iceryoides* Green has also been recorded on cotton.

Ferrisiana virgata has the following alternate hosts: *Lycopersicum esculentus*, *Hibiscus* sp., pepper vines, *Lantana*, *Anona squamosa*, and *Sesbania* sp. *Pseudococcus corymbatus* Green is observed on mango, potato, soyabean, *Casuarina* sp., *Citrus*, and *Melochia*. *Diadiplosis indica* Felt. has been found parasitizing it in India (Thompson, 1950).

Maheswariah and Puttarudriah (1956) suggest, for control, spraying with a contact insecticide and cutting and burning of badly infested plants.

Natural enemies of *P. corymbatus* Green include *Gitonides perspicax* Knab. (*Drosophilidae*), *Scymnus nubilis* Muls. (*Coccinellidae*), *Diadiplosis indica* Felt. (*Cecidomyiidae*), and *Eublemma quadrilineata* (*Noctuidae*). Caterpillars of *Spalgis epius* Westwood are also known to feed on these mealy bugs.

Thompson (1950) has listed *Chalcid* sp., as parasitizing *Phenacoccus iceryoides* in India. Fletcher (1919) has recorded *Brumus suturalis* F., feeding on *Pseudococcus* sp. on cotton.

SCALE INSECTS, *Pulvinaria maxima* Green, *Saissetia nigra* Nietn., and *Cerococcus hibisci* Green

Three species of scale insects are met with on cotton. They are *Pulvinaria maxima* Green, *Saissetia nigra* Nietn., and *Cerococcus hibisci* Green.

Pulvinaria maxima is known as a serious pest of neem tree (*Melia*) and *Jatropha curcos*. Eggs are laid in batches of 650-900 in ovisacs on leaves and shoots, which hatch in about 12-14 days. There are 6-7 generations in one year which overlap, one generation being completed in 6½-8 weeks. Its natural enemies include *Anicetus ceylonensis* How., *Encyrtus flavus* How., *Aphycus* sp., *Perrissopterous* sp., *Scutellista cyanea* Mots., and the braconid, *Megalomum* sp. The predators include *Scymnus coccivora* Ayyar, *Eublemma scitula* Ramb., and *Leucopis luteicornis* Mal.

Saissetia nigra Nietn., commonly known as the Black Bug, has been recorded usually as a minor pest and rarely as a major pest on cotton. It also attacks *Abelmoschos esculentus*, *Coffea arabica*, *Ricinus communis*, *Hygrophila spinosa*, *Croton* sp., and a number of other host plants. Its natural enemies include the chalcid parasite, *Scutellista cyanea* Mots., which exercises an effective check, as stated by Ayyar (1930). Pruthi and Mani (1940) in addition to this species mention *Anicetus ceylonensis* How., *Encyrtus barbatus* Timb., *Encyrtus kotinski* Full., *Anysis saissetiae* Ashm., *Coccophagus longifasciatus* How., and *Eucomys lecaniorum* Meyr. as parasitizing the scale. Thompson (1950) has catalogued in addition *Aneristus ceroplastae* How., and *Encyrtus lecaniorum* Meyr., as parasitizing the scale in India. The caterpillar, *Eublemma scitula* Ramb. is known to feed on the scale.

Cerococcus hibisci Green, is known as 'Yellow Scale of Cotton'. Though

isolated plants are often badly covered by this scale, it is only a minor pest of cotton. It has also been recorded on brinjals, *Hibiscus liliflorus*, *H. rosa sinensis* and *Tephrosia candida*.

Control measures recommended against the scale insects on cotton are the removal of affected plants and burning them, and spraying with a contact insecticide like fish-oil rosin soap.

THRIPS, *Scirtothrips dorsalis* Hood and *Thrips tabaci* Lind.

The above two species are pests of cotton in India. Of the two, *Thrips tabaci* is more common and widely distributed. *Scirtothrips dorsalis* is generally common in the South. Shumsher Singh (1945) has given keys for identification of Indian species. Karny (1926) has given a complete list of known thrips from South India and has included the new species, *Anaphothrips oligochaetus* in flowers and shoots of cotton. Nearly 44 species of thrips have been recorded on cotton in different parts of the world (Hargreaves, 1948).

Both nymphs and adults lacerate the plant tissue and suck the sap by means of a pharyngeal pump, first devitalising and ultimately killing the attacked part of the plant. When the attack is severe, they cause significant reduction in yield. Bhat and Patel (1954) estimated damage to cotton by thrips at 232 lb. per acre under normal conditions.

The eggs are kidney-shaped and are laid in the tender leaves. The life cycle is completed in 4-5 weeks. In the Punjab the life cycle of *Thrips tabaci* is completed in 12-21 days as follows:

Egg stage	5-9 days
Nymphal stage	4-6 days
Pre-pupal and pupal stages	3-6 days

In Madras, thrip attack starts generally in November, whereas in Marathwada the attack starts in August. Pupation takes place in the soil.

The alternate host plants of both the thrips are as follows:

<i>Thrips tabaci</i>	—	Onion and cabbage
<i>Scirtothrips dorsalis</i>	—	Castor, brinjal, groundnut, chillies, Deccan-hemp and 'amaltas' — a wild plant

Natural Enemies. The eggs of both the species are parasitised by *Thripoctenus brui* Vuillet, and nymphs by *Triphleps tantilus* Motsch. A mite *Camspid* sp., predares on them.

Control Measures. Maheswariah and Puttarudriah (1956) state that tobacco decoction 1 lb. + 1½ gallons. of water + ½ lb. soap spray when used in the early stages of the crop is very effective against the thrips.

Nangpal (1948) reports that nicotine sulphate when used in the early stages of the crop is very effective against both the species of thrips. Dusting BHC 5 per cent. is quite effective. Smooth-leaved Egyptian cottons are less susceptible to *T. tabaci* than hairy Indian and American varieties. Patel,

et al. (1956) recommended use of 5 per cent. DDT used in admixture with sulphur in the proportion of 1:1. If the insect population increases after some time, they suggest the repetition of the dusting after a fortnight's interval. They warn that the DDT mixture should not be used for Asiatic cottons, but is safe for the American varieties. These authors also suggest the use of nicotine sulphate 1 part in 60 parts of water with 4 lb. of soap. Experiments carried out by Sardar Singh and Sidhu (1958) have shown that spraying the infested crop with 0.1 per cent. DDT suspension or 0.02 per cent. endrin emulsion resulted in complete mortality of the pest within a week of the treatment.

MITE PESTS

Two acarine pests are noted to cause damage to cotton crop. They are the woolly mite, *Eriophyes gossypii* Banks and *Tetranychus telarius* L. The former is said to be a more serious pest than the latter. It may be mentioned that *T. telarius* is well-known as a serious pest in other cotton growing countries. Chenna Basavanna and Puttarudriah (1959) have recently recorded *Hemitarsonemus latus* Banks as a potential pest of cotton in Mysore.

Eriophyes gossypii is more common on the *herbaceum* variety of cotton in Surat and Broach in Bombay State, and Dharwar in Mysore State. Notes on the mite have been given by Jhaveri (1921). The mite lives under the tissues of the epidermis of the leaf and causes irritation due to which a growth of dense whitish hair arises on both surfaces of the leaf as well as on the stem. The attacked leaf remains stunted, curls up and becomes hard and crisp. Heavily infested plants shed their bolls. The eggs are whitish in colour and oval in shape. No alternative hosts of this mite are known. Damage to Sea Island cotton caused by this in Puerto Rico has been studied in detail by Fife (1937).

Tetranychus telarius, known as red mite is also an important mite pest of cotton. It is also termed as the green-house red spider mite in England and is known to cause damage to apples, French beans, etc. Notes on this species have been given by Cherian (1938).

Misra (1913) refers to the occurrence of *Tetranychus bioculatus* Wood-Mason also, on cotton. In Madras and Andhra States, *Eutetranychus banksi* (McGregor) misidentified as *Anychus latus* Can. & Fan. has been recorded.

In earlier years, as stated by Shepherd (1917), the general custom in India had been to destroy cotton plants which are heavily infested by the mite, *Eriophyes gossypii*, when successive crops are to be grown on the same land. The experiment of burying them in, as green manure, is also reported to give excellent results. It has also been stated by him that the new crops have not been infested with the mite when the old plants have been pulled up instead of being cut down, provided that this is done six or eight weeks before planting the new cotton. According to Jhaveri (1921) infestation was only about 0.4

to 0.5 per cent. compared with 3 per cent. or more in the untreated plots when good quality cotton seeds were steeped for ten minutes in a solution of one part Mercury perchloride in 100 parts of water, dried in shade and later planted. Hargreaves (1934) states that the prevalence of an undetermined Tetranychid, which causes yellow mottling of the leaves and finally their death, appears to be correlated with poor soil and dry weather.

Spraying with insecticides, such as, DDT and BHC has aggravated the red mite control problem. They have helped in a build-up of mites by affecting the predators of the mites adversely. Experiments conducted by Kulkarni and Katagihallimath (1955) in Bombay State have shown the build up of *T. telarius* and aphids in the cotton plots sprayed with DDT and BHC. Maheswariah and Puttarudriah (1956), in Mysore State, recommend spraying affected plants with lime-sulphur wash prepared with 1 part of lime, 2 parts of sulphur and 15 parts of water and diluted 8 times again, before spraying, which controls the mite effectively. For control of *T. telarius*, sulphur is found effective. De and Konar (1956) have conducted a test against Tetranychid mites on infested cotton plants in pots by spraying with 0.3 or 0.5 per cent. commercial Schradan in water. Both of them were not found to be effective. Recent developments in acaricidal formulations like aramite EPT (O-ethyl O-P-nitrophenyl benzene thiono-phosphonate), 'Ovotran' (P-chlorophenyl P. chloro-benzene sulphonate), and Chlorobenzelate R6199 give promise of satisfactory control of mites.

COTTON BOLL WEEVIL, *ANTHONOMUS GRANDIS* BOHEMAN— A COTTON PEST NOT OCCURRING IN INDIA

Origin and Spread. Although a large number of pests attack the cotton crop in India, there are still a number of insect pests occurring in other countries, which have not yet gained an entry into this country. Amongst these is the cotton boll weevil, *Anthonomus grandis* Boheman. No insect in the world has gained as much notoriety as the cotton boll weevil. This insect was first described from specimens received from Vera Cruz, Mexico, in 1843. It was for the first time found in the U.S.A., doing damage to the cotton crop at Brownsville, Texas, in 1892, and probably had crossed the Rio Grande river by natural spread from Mexico a year or so prior to that. Since then it has spread almost throughout the southern part of the U.S.A. and has been the most destructive pest of cotton in that country. The more recent estimates place the loss in the U.S.A. at 3,000,000 to 5,000,000 bales of cotton a year or from 22-40 per cent. of the normal production (Fig. 40).

Distribution. The boll weevil is now found in Mexico, the U.S.A., Guatemala and Costa Rica in North America, Cuba and Haiti in West Indies, and Venezuela in South America.

Host Plants. The boll weevil, so far as it is known, is confined almost exclusively to cotton for reproduction, but adults have been known to feed

on Okra (*bhendi*), hollyhock and hibiscus also. A variety of the weevil called *A. thurberiae* Peirce, breeds on wild cotton plant, *Thurberia*, in Arizona, the U.S.A. and Mexico.

Steps Taken by the Government of India to Prevent the Entry of this Pest into India. Prior to the First World War, India imported the American cotton in varying quantities, averaging about 26,000 bales per annum. In 1920-21, importations were again heavy and in view of the enormous damage caused by the cotton boll weevil in the western hemisphere, the question arose whether this pest might not find its way into India through the medium of imported cotton bales. This question was raised by two Chambers of Commerce. Fletcher (1924) drew attention to its habits and the enormous loss it causes to the cotton crop in the U.S.A. As there was a definite risk of the pest being introduced, the damage to the Indian cotton crop might be incalculable, specially because of the climatic conditions of the Indian cotton growing tracts being similar to those of the American cotton belts. The Indian Central Cotton Committee, therefore, recommended to the Government of India that in future the American cotton should be imported on the condition that it was fumigated at Bombay, the port of entry. To enforce this, the Government of India framed rules and issued a Notification under the Destructive Insect Pests Act of 1914 which became effective from the 1st December, 1925. Mackie (1925) conducted tests with HCN with a view to fumigating American cotton effectively against the boll weevil. Turner and Sen (1928) later made more detailed study regarding the use of hydrocyanic acid gas and evolving a satisfactory method for fumigation of American cotton on a large scale. Liston Cyanide Fumigator was used for the generation of HCN gas and fumigation of the cotton bales was carried out in holds of barges covered with gas-proof cloth covers. Recently the process has again been described by Subramanyam (1956). However, when very large number of bales arrive together in a number of ships at the same time, these bales are fumigated in large godowns which are made air-tight for fumigation. The fumigation of American cotton bales at Bombay was being supervised by the Secretary, Indian Central Cotton Committee till 1952. In January, 1953, this work was taken over by the Directorate of Plant Protection, Quarantine and Storage of the Ministry of Food and Agriculture, Government of India.

In 1950, on account of very heavy imports of American cotton at Bombay, fumigation facilities available there were found to be inadequate. Arrangements, were, therefore, made at the Madras Port to fumigate, in large godowns, the American cotton bales which were intended for use by the mills in South India. In 1955 these facilities for fumigation were made available at the port of Cochin also so that there would be no congestion at any of the prescribed ports of entry.



Fig. 40. Cotton Boll Weevil (*Anthonomus grandis* Boheman) 1. Cotton Plant Attacked by Boll Weevil. 2. Square Showing Puncture made by Boll Weevil. 3 and 4. Sectioned Square Showing Larva or Pupa of the Weevil in the Cell. 5. Weevil Emerging out. 6. Cotton Boll Sectioned to Show Attacking Weevil and Larva in Cell. 7. Larva, Lateral View. 8. Pupa, Ventral View. 9. Adult Dorsal View.

LIST OF INSECT AND MITE PESTS OF COTTON IN INDIA

Apart from the insect pests noted on cotton described so far, a number of other insects have been noted on cotton. They are mostly minor pests and seldom assume importance. Nangpal (1948) has listed most of the insects attacking cotton in India, while Hargreaves (1948) has also included these in his list of recorded cotton insects of the world. In the list given below (Table 45), the few omissions made by these authors have been rectified. Further, the newly recorded insects, like those by Thirumala Rao (1953), Kevan (1954), Sardar Singh and Gurcharan Singh (1957), Sen Gupta and Behura (1957), and Puttarudriah, (1958b, c), have also been added.

TABLE 45. LIST OF INSECT AND MITE PESTS OF COTTON IN INDIA

Name of the pest	Species	Order	Family
Cotton Seedlings			
Large brown cricket	<i>Brachytrypes portentosus</i> Licht.	Ortho:	Gryllidae
Cricket <i>tid</i>	<i>Gryllus viator</i> Kirby	"	"
Black-headed cricket <i>tid</i>	<i>Gryllulus domesticus</i> Linn.	"	"
Surface grasshopper or	<i>Chrotogonus</i> sp.	"	Acridiidae
Dusky groundhopper	<i>Chrotogonus saussurei</i> Boll.	"	"
	<i>C. brachypterus</i> (Blanch.)	"	"
	<i>C. oxypterus</i> (Blanch.)	"	"
Surface grasshopper	<i>Ailopus tamulus</i> Fb.	"	"
Surface grasshopper or	<i>Atractomorpha crenulata</i> F.	"	"
Tobacco grasshopper			
Desert locusts	<i>Shistocerca gregaria</i> Fst.	"	"
Dark brown weevil	<i>Atactogaster fnitimus</i> Fst.	Coleo:	Curculionidae
Grey weevil	<i>Mylocerus blandus</i> Fst.	"	"
Greasy surface caterpillar or	<i>Agrotis flammatra</i> Schiff.	Lepido:	Noctuidae
Cutworm			
Leaf worm	<i>Prodenia litura</i> F. (<i>littoralis</i> Boisd.)	"	"
Cutworm	<i>Euxoa segetum</i> Schiff.	"	"
	<i>E. spinifera</i> Kb.	"	"
Lesser leaf worm	<i>Laphygma exigua</i> kb.	"	"
Red hiary caterpillar	<i>Amsacta moorei</i> Butler	"	Arctiidae
	<i>Cerococcus hibisci</i> Green	Hemip:	Coccidae
Leaves			
(i) <i>Biting</i>			
Leaf ant	<i>Solenopsis geminata</i> Fb.	Hymeno:	Formicidae
Leaf roller	<i>Sylepta derogata</i> Fb.	Lepido:	Pyalidae
	<i>Phycita infusella</i> Meyr.	"	"
Green semilooper	<i>Anomis flava</i> Fb. (<i>Cosmophila indica</i> Gn.)	"	Noctuidae
Semilooper	<i>A. fulvida</i> Guen.	"	"
	<i>Acontia graellsii</i> Fstsh.	"	"
	<i>A. intersepta</i> Guen.	"	"
	<i>A. malvae</i> Esper	"	"
Cotton semilooper	<i>Tarache notabilis</i> Wlk.	"	"
Semilooper	<i>T. nitidula</i> Fb.	"	"
	<i>T. opalinoides</i> Guen.	"	"
	<i>T. marmoralis</i> Feb.	"	"
	<i>T. basifera</i> Wlk.	"	"
	<i>Spodoptera pecten</i> Gn.	"	"

Name of the pest	Species	Order	Family
Leaf worm	<i>Prodenia litura</i> Fb.	Lepido:	Noctuidae
	<i>Laphygma exigua</i> Hb.	"	"
	<i>Mocis (Pelamia) undata</i> Fb.	"	"
Bihar hairy caterpillar	<i>Diacrisia obliqua</i> Wlk.	"	Arctiidae
	<i>Amsacta albistriga</i> Wlk.	"	"
	<i>A. moorei</i> Swinh.	"	"
Black hairy caterpillar	<i>Aloa (Esigene) lactinea</i> Gram.	"	"
	<i>Pericallia ricini</i> F.	"	"
Hairy caterpillar	<i>Euproctis fraterna</i> Moore	"	Lymantriidae
	<i>E. lunata</i> Wlk.	"	"
	<i>E. varians</i> Wlk.	"	"
	<i>Porthesia xanthorrhoea</i> Koll.	"	"
	<i>Nygmia fraterna</i> Moore	"	"
	<i>N. varians</i> Wlk.	"	"
	<i>N. xanthorrhoea</i> Koll.	"	"
Leaf miner	<i>Lithocolletis triarcha</i> Meyr.	"	Oracilariidae
Leaf perforator	<i>Bucculatrix loxophila</i> Meyr.	"	Lyonectidae
White weevil	<i>Myloccerus maculosus</i> Desbr. (<i>undecimpus-tulatus</i> Fst., var. <i>maculosus</i> Desbr.)	Coleo:	Curculionidae
Weevil	<i>M. discolor</i> var. <i>variegata</i> Boheman.	"	"
	<i>M. laetivirens</i> Mshl.	"	"
	<i>M. transmarinus</i> Hbst.	"	"
	<i>M. sabulosus</i> Mshll.	"	"
Black weevil	<i>Tanymecus indicus</i> Fst.	"	"
	<i>T. princeps</i> Fst.	"	"
	<i>T. hispidus</i> Mshll.	"	"
	<i>T. sciurus</i> Oliv.	"	"
	<i>Lepropus lateralis</i> F.	"	"
Green weevil	<i>Astycus lateralis</i> Fb.	"	"
Desert locust	<i>Schistocera gregaria</i> Forsk.	Ortho:	Acridiidae
	<i>Acrida exaltata</i> Wlk.	"	"
	<i>Catantops annexus</i> Bol.	"	"
Large brown cricket	<i>Brachytrypes potentosus</i> Licht.	"	Gryllidae
	<i>Gryllulus domesticus</i> L.	"	"
	<i>G. viator</i> Kby.	"	"
	<i>Poecilocerus pictus</i> F.	"	Acrididae
	<i>Oxya velox</i> F.	"	"
	<i>Chrotogonus saussurei</i> Bol.	"	"
	<i>Cyrtacanthracis ranacea</i> Stoll. (<i>tatarica</i> L.)	"	"
	<i>C. rosea</i> Deg.	"	"
	<i>Acrida exaltata</i> Wlk.	"	"
	<i>Colasposoma auripenne</i> Motsch.	Coleo:	Eumolpidae
(ii) Sucking			
Cotton Aphis	<i>Aphis gossypii</i> Glover	Hemip:	Aphididae
Cotton white-fly	<i>Bemisia tabaci</i> Gen. (<i>gossypiperda</i> M. & L.)	"	Aleurodidae
Jassid or Leaf hopper	<i>Empoasca devastans</i> Dist.	"	Jassidae
	<i>E. formosana</i> Paoli	"	"
	<i>E. punjabensis</i> Pruthi	"	"
	<i>E. kerri</i> var. <i>motti</i> Pruthi	"	"
	<i>E. minor</i> Pruthi	"	"
	<i>E. notata</i> Mell.	"	"

Name of the pest	Species	Order	Family
Jassid or Leaf hopper (contd.)	<i>Empoasca melongena</i> Pruthi	Hemip:	Jassidae
	<i>E. gossypii</i> Banks	"	"
	<i>Ricania fenestrata</i> Fab.	"	Fulgoridae
	<i>Eurybrachys tomentosa</i> Fb.	"	"
	<i>Otinotus oneratus</i> Walk.	Homop:	Membracidae
Mealy bug	<i>Ferrisia virgata</i> (Ckll.)	Hemip:	Coccidae
	<i>P. corymbatus</i> Green	"	"
	<i>Phenacoccus hirsutus</i> Green	"	"
	<i>P. iceryoides</i> Green	"	"
Neem (Melia) scale	<i>Pulvinaria maxima</i> Green	"	"
Black scale or black bug	<i>Saissetia nigra</i> Nietn.	"	"
Yellow scale of cotton	<i>Cerococcus hibisci</i> Green	"	"
Cotton scale	<i>Chionaspis</i> sp.	"	"
Tube-making cercopid	<i>Machaerota planitiae</i> Dist.	"	Cercopidae
Capsid bug	<i>Ragnus importunatus</i> D.	"	Capsidae
Thrip	<i>Scirtothrips dorsalis</i> Hd.	"	Thysanoptera
	<i>Thrips tabaci</i> L.	"	"
Mites	<i>Eriophyes gossypii</i> Banks	Acari	
	<i>E. telarius</i> L.	"	
	<i>Hemitarsonemus laetus</i> Banks	"	
	<i>Tetranychus bioculatus</i> Wood-Mason	"	
Stems and Branches			
Large brown cricket	<i>Brachytrypes portentosus</i> Licht.	Ortho:	Gryllidae
Stem borer	<i>Sphenoptera gossypii</i> Cotes	Coleo:	Buprestidae
	<i>Sinoxylon sudanicum</i> Lesne	"	"
Stem weevil	<i>Pempheres affinis</i> Fst.	"	Circulionidae
	<i>Episomus lacerta</i> F.	"	"
	<i>Alcides affaber</i> Auriv.	"	"
	<i>A. leopardus</i> Oliv.	"	"
	<i>A. fabrici</i> Fb.	"	"
	<i>Alcidodes (Alcides) mysticus</i> Faust.	"	"
Red coffee borer	<i>Zeuzera coffeae</i> Nietn.	Lepido:	Cassidae
	<i>Acrocercops zygonoma</i> Meyr.	"	Tineidae
	<i>Phycita infusella</i> Meyr.	"	Pyralidae
Black scale	<i>Saissetia nigra</i> Nietn.	Hemip:	Coccidae
Yellow scale of cotton	<i>Cerococcus hibisci</i> Green	"	"
	<i>Eurybrachys tomentosa</i> F.	"	Fulgoridae
	<i>Machaerota ensifera</i> Burn.	"	Cercopidae
	<i>Otinotus oneratus</i> Walk.	Homop:	Membracidae
Buds and Shoots			
Bud moth	<i>Phycita infusella</i> Meyr.	Leipdo:	Pyralidae
Spotted bollworm	<i>Earias fabia</i> Stoll.	"	Noctuidae
Spotted or spiny bollworm	<i>E. insulana</i> Boisd.	"	Pyralidae
Pink bollworm	<i>Platyedra gossypiella</i> Saund.	"	Gelechiidae
	<i>Nezara viridula</i> L., and var.	Hemip:	Pentatomidae
	<i>Ricania fenestrata</i> Fab.	"	Fulgoridae
Floral Buds (Squares) and Flowers			
Floral bud maggot	<i>Dasyneura (contarinia) gossypii</i> Felt.	Diptera:	Cecidomyiidae
Spotted bollworm	<i>Earias fabia</i> Stoll.	Lepido:	Noctuidae
Spotted or spiny bollworm	<i>E. insulana</i> Boisd.	"	"

Name of the pest	Species	Order	Family
Gram caterpillar or American bollworm	<i>Heliothis (Chloridea) armigera</i> Hubner	Lepido	Noctuidae
Pink bollworm	<i>Platyedra gossypiella</i> Saund.	Lepido:	Gelechiidae
Blister beetle	<i>Zonabris pustulata</i> Thnb.	Coleo:	Meloidae
Thrip	<i>Anaphothrips oligochaetus</i> Karny	"	Thysanoptera
White ants	<i>Microtermes obesi</i> Holmgren	Isop:	Termitidae
	<i>Odontotermes (Terms) obesus</i> (Ramb.)	"	"
Green Bolls			
(i) Biting			
Pink bollworm	<i>Platyedra gossypiella</i> Saund.	Lepido:	Gelechiidae
	<i>Dichocrocis punctiferalis</i> Gn.	"	Pyalidae
Spotted or spiny bollworm	<i>E. insulana</i> Boisd.	"	Noctuidae
	<i>E. fabia</i> stoll.	"	"
Gram caterpillar or American bollworm	<i>Heliothis armigera</i> Hubner	"	"
Red bollworm	<i>Rabila frontalis</i> Wlk.	"	"
Grasshopper	<i>Catantops</i> sp.	Ortho:	Acrididae
Black weevil	<i>Amorphoidea arcuata</i> M.	Coleo:	Curculionidae
	<i>Monolepta signata</i> Ol.	"	Galeracidae
(ii) Sucking			
Red cotton bug	<i>Dysdercus cingulatus</i> Fb.	Hemip:	Pyrrhocoridae
	<i>D. olivaceus</i> Fb.	"	"
Green bug	<i>Nezara viridula</i> L.	"	Pentatomidae
	<i>Helopeltis antonii</i> Signoret	"	Capsidae
Capsid bug	<i>Ragnus morosus</i> Ball.	"	"
	<i>R. flavomaculatus</i> Ball.	"	"
	<i>Serinatha augur</i> Fb.	"	Coreidae
	<i>Leptocoris augur</i> F. (<i>Serinatha</i>)	"	"
	<i>Clavigralla horrens</i> Dohrn.	"	"
	<i>Lygaeus pandurus</i> Scop.	"	"
	<i>L. hospes</i> Fb.	"	"
Open Bolls			
Dusky cotton bug	<i>Oxycarenus laetus</i> Kby.	"	Lygaeidae
	<i>Pyroderces gossypiella</i> Sn.	Lepido:	Tineidae
	<i>Dysdercus cingulatus</i> F.	"	Pyrrhocoridae
	<i>D. olivaceus</i> F.	"	"
Roots			
White ants	<i>Termites</i>	Isoptera	
White weevil	<i>Mytillocerus maculosus</i> Desh.	Coleo:	Curculionidae
	<i>Araecerus fasciculatus</i> Deg.	"	Anthribidae
Seeds			
Dusky cotton bug	<i>Oxycarenus laetus</i> Kby.	Hemip:	Lygaeidae
	<i>Alphitobius laevigatus</i> F. (<i>piceus</i> Ol.)	Coleo:	Tenebrionidae
Rice mealworm	<i>Corcyra cephalonica</i> Staint.	Lepido:	Pyalidae

COMMON INSECT AND MITE PESTS OF COTTON IN DIFFERENT STATES

Ayyar (1932) in Madras; Trehan and Pingale (1946), and Patel and Katarki (1957) in Bombay; Maheswariah and Puttarudriah (1956) in Mysore; Sen Gupta and Behura (1957) in Orissa; Sardar Singh and Gurcharan Singh (1957) in the Punjab; and Srivastava (1959) in Uttar Pradesh, have listed the different pests attacking cotton in their respective States. The Directorate of Plant Protection, Quarantine and Storage, Ministry of Food and Agriculture, Government of India, have also published the more important pests in different States along with the methods of control adopted. Information collected from these sources as well as by correspondence with the Entomologists in different States has been utilised in preparing the list given below:

State	Common cotton pests
Andhra Pradesh	<ol style="list-style-type: none"> 1. <i>Aphis gossypii</i> Glov. 2. <i>Dysdercus cingulatus</i> F. 3. <i>Earias fabia</i> Stoll 4. <i>Earias insulana</i> Boisd. 5. <i>Empoasca devastans</i> Dist. 6. <i>Eutetranychus banksi</i> (McGregor) (<i>Anychus latus</i> Can. & Fan. mis-identification) 7. <i>Heliothis armigera</i> Hübn. 8. <i>Monolepta signata</i> Ol. 9. <i>Oxycarenus laetus</i> Kirby 10. <i>Pempheres affinis</i> Fst. 11. <i>Phenacoccus</i> sp. 12. <i>Platyedra gossypiella</i> Saund. 13. <i>Pseudococcus</i> sp. 14. <i>Sylepta derogata</i> Fabr. 15. <i>Thrips tabaci</i> Lind.
Assam	<ol style="list-style-type: none"> 1. <i>Ailopus tamulus</i> Fb. 2. <i>Aphis gossypii</i> Glov. 3. <i>Atractomorpha crenulata</i> Fabr. 4. <i>Brachytrypes portentosus</i> Licht. 5. <i>Chrotogonus</i> spp. 6. <i>Diacrisia obliqua</i> Wlk. 7. <i>Dysdercus cingulatus</i> F. 8. <i>Earias insulana</i> Boisd. 9. <i>Empoasca devastans</i> Dist. 10. <i>Empoasca</i> spp. 11. <i>Myllocerus maculosus</i> Dist.

State	Common cotton pests
Assam (contd.)	12. <i>Oxycarenum laetus</i> Kirby 13. <i>Platyedra gossypiella</i> Saund. 14. <i>Pemphres affinis</i> Fst. 15. <i>Sphenoptera gossypii</i> Cotes 16. <i>Sylepta derogata</i> Fabr.
Bihar	1. <i>Bemisia tabaci</i> Genn. 2. <i>Dysdercus cingulatus</i> F. 3. <i>Earias fabia</i> Stoll 4. <i>Earias insulana</i> Boisd. 5. <i>Empoasca devastans</i> Dist. 6. <i>Myllocerus maculosus</i> Desb. 7. <i>Oxycarenum laetus</i> Kirby 8. <i>Pemphres affinis</i> Fst. 9. <i>Platyedra gossypiella</i> Saund. 10. <i>Sylepta derogata</i> Fabr.
Bombay	1. <i>Acontia</i> sp. 2. <i>Amsacta moorei</i> Swinh. 3. <i>Aphis gossypii</i> Glov. 4. <i>Bemisia tabaci</i> Genn. 5. <i>Chrotogonus</i> sp. 6. <i>Cosmophila indica</i> Gn. 7. <i>Cyrtacanthacris ranacea</i> S. 8. <i>Dysdercus cingulatus</i> F. 9. <i>Earias fabia</i> Stoll 10. <i>Earias insulana</i> Boisd. 11. <i>Empoasca devastans</i> Dist. 12. <i>Eriophyes gossypii</i> Banks 13. <i>Laphygma exigua</i> Hübn. 14. <i>Myllocerus maculosus</i> Desb. 15. <i>Oxycarenum laetus</i> Kirby 16. <i>Phycita infusella</i> Meyr. 17. <i>Platyedra gossypiella</i> Saund. 18. <i>Pseudococcus</i> sp. 19. <i>Sphenoptera gossypii</i> Cotes 20. <i>Sylepta derogata</i> Fabr. 21. <i>Tarache nitidula</i> F.
Delhi	1. <i>Aphis gossypii</i> Oliv. 2. <i>Bemisia tabaci</i> Genn. 3. <i>Earias fabia</i> Stoll

State	Common cotton pests
Delhi (contd.)	<ol style="list-style-type: none"> 4. <i>Earias insulana</i> Boisd. 5. <i>Empoasca devastans</i> Dist. 6. <i>Sylepta derogata</i> Fabr.
Kerala	<ol style="list-style-type: none"> 1. <i>Amsacta albistriga</i> Wlk. 2. <i>Aphis gossypii</i> Glov. 3. <i>Dysdercus cingulatus</i> Fabr. 4. <i>Earias fabia</i> Stoll 5. <i>Earias insulana</i> Boisd. 6. <i>Euproctis fraterna</i> Moore 7. <i>Heliothis armigera</i> Hübn. 8. <i>Oxycarenum laetus</i> Kirby 9. <i>Pemphres affinis</i> Fst. 10. <i>Pericallia ricini</i> F. 11. <i>Phycita infusella</i> Meyr. 12. <i>Platyedra gossypiella</i> Saund. 13. <i>Sphenoptera gossypii</i> Cotes 14. <i>Sylepta derogata</i> Fabr.
Madhya Pradesh	<ol style="list-style-type: none"> 1. <i>Aphis gossypii</i> Glov. 2. <i>Cosmophila indica</i> Gn. 3. <i>Dysdercus cingulatus</i> F. 4. <i>Earias fabia</i> Stoll 5. <i>Earias insulana</i> Boisd. 6. <i>Empoasca devastans</i> Dist. 7. <i>Myllocerus maculosus</i> Desb. 8. <i>Oxycarenum laetus</i> Kirby 9. <i>Platyedra gossypiella</i> Saund. 10. <i>Sphenoptera gossypii</i> Kirby 11. <i>Sylepta derogata</i> Fabr.
Madras	<ol style="list-style-type: none"> 1. <i>Acontia graellsii</i> Fsth. 2. <i>Alcides affaber</i> Auriv. 3. <i>Alcidodes mysticus</i> Fst. 4. <i>Amorphoidea arcuata</i> Motsch 5. <i>Amsacta albistriga</i> Wlk. 6. <i>Anomis flava</i> F. 7. <i>Aphis gossypii</i> Glov. 8. <i>Atactogaster finitimus</i> Fst. 9. <i>Catantops annexus</i> Bol. 10. <i>Cerococcus hibisci</i> Green 11. <i>Cyrtacanthacris ranacea</i> Stoll 12. <i>Dasyneura gossypii</i> Felt.

State	Common cotton pests
Madras (contd.)	13. <i>Dysdercus cingulatus</i> Fabr. 14. <i>Earias fabia</i> Stoll 15. <i>Earias insulana</i> Boisd. 16. <i>Empoasca devastans</i> Dist. 17. <i>Euproctis fraterna</i> Moore 18. <i>Eutetranychus banksi</i> (McGregor) (<i>Anychus latus</i> Can. & Fan. mis- identification) 19. <i>Ferrisiana virgata</i> (Ckll.) 20. <i>Monolepta signata</i> Ol. 21. <i>Oxycarenum laetus</i> Kirby 22. <i>Pempheres affinis</i> Fst. 23. <i>Pericallia ricini</i> F. 24. <i>Phycita infusella</i> Meyr. 25. <i>Platyedra gossypiella</i> Saund. 26. <i>Pseudococcus corymbatus</i> Green 27. <i>Pulvinaria maxima</i> Green 28. <i>Rabida frontalis</i> Wlk. 29. <i>Saissetia nigra</i> Nietn. 30. <i>Sphenoptera gossypii</i> Cotes 31. <i>Sylepta derogata</i> Fabr. 32. <i>Tarache nitidula</i> F. 33. <i>Thrips tabaci</i> Lind. 34. <i>Zeuzera coffeae</i> Nietn. 35. <i>Zonabris pustulata</i> F.
Mysore	1. <i>Alcides leopardus</i> Oliv. 2. <i>Anomis flava</i> F. 3. <i>Aphis gossypii</i> Glov. 4. <i>Dysdercus cingulatus</i> F. 5. <i>Earias fabia</i> Stoll 6. <i>Earias insulana</i> Boisd. 7. <i>Eriophyes gossypii</i> Banks 8. <i>Ferrisiana virgata</i> (Ckll.) 9. <i>Heliothis armigera</i> Hübn. 10. <i>Laphygma exigua</i> Hübn. 11. <i>Monolepta signata</i> Ol. 12. <i>Oxycarenum laetus</i> Kirby 13. <i>Pempheres affinis</i> Fst. 14. <i>Phycita infusella</i> Meyr. 15. <i>Platyedra gossypiella</i> Saund. 16. <i>Ricania fenestrata</i> Fab.

State	Common cotton pests
Mysore (contd.)	17. <i>Scirtothrips dorsalis</i> Hood 18. <i>Sphenoptera gossypii</i> Kirby 19. <i>Sylepta derogata</i> Fabr. 20. <i>Thrips tabaci</i> Lind.
Orissa	1. <i>Anomis flava</i> F. 2. <i>Aphis gossypii</i> Glov. 3. <i>Chrotogonus brachypterus</i> Blanchard 4. <i>Dysdercus cingulatus</i> Fabr. 5. <i>Earias fabia</i> Stoll 6. <i>Earias insulana</i> Boisd. 7. <i>Empoasca devastans</i> Dist. 8. <i>Myllocerus</i> sp. 9. <i>Otinotus oneratus</i> W. 10. <i>Oxycarenum laetus</i> Kirby 11. <i>Pempheres affinis</i> Fst. 12. <i>Platyedra gossypiella</i> Saund. 13. <i>Phycita infusella</i> M. 14. <i>Sylepta derogata</i> Fabr.
Punjab	1. <i>Acontia</i> sp. 2. <i>Ailopus tamulus</i> Fabr. 3. <i>Amsacta moorei</i> Swinh. 4. <i>Aphis gossypii</i> Glov. 5. <i>Bemisia tabaci</i> Genn. 6. <i>Chrotogonus brachypterus</i> Blanchard 7. <i>Dysdercus cingulatus</i> F. 8. <i>Earias fabia</i> Stoll 9. <i>Earias insulana</i> Boisd. 10. <i>Empoasca devastans</i> Dist. 11. <i>Gryllus viator</i> Kirby 12. <i>Laphyma exigua</i> Hübn. 13. <i>Microtermes obesi</i> Holmgren 14. <i>Myllocerus blandus</i> Faust. 15. <i>Myllocerus maculosus</i> Desb. 16. <i>Odontotermes (Termes) obesus</i> (Ramb.) 17. <i>Oxycarenum laetus</i> Kirby 18. <i>Phycita infusella</i> Meyr. 19. <i>Platyedra gossypiella</i> Saund. 20. <i>Sphenoptera gossypii</i> Cotes 21. <i>Sylepta derogata</i> Fabr. 22. <i>Tarache notabilis</i> Walker 23. <i>Thrips tabaci</i> Lind.

State	Common cotton pests
Rajasthan	<ol style="list-style-type: none"> 1. <i>Amsacta albistriga</i> Wlk. 2. <i>Aphis gossypii</i> Glov. 3. <i>Bemisia tabaci</i> Genn. 4. <i>Cosmophila indica</i> Genn. 5. <i>Cosmophila erosa</i> Hb. 6. <i>Cyrtacanthacris ranacea</i> S. 7. <i>Dysdercus cingulatus</i> F. 8. <i>Dysdercus koenigii</i> Fabr. 9. <i>Earias fabia</i> Stoll 10. <i>Earias insulana</i> Boisd. 11. <i>Empoasca devastans</i> Dist. 12. <i>Euproctis fraterna</i> Moore 13. <i>Laphygma exigua</i> Hübn. 14. <i>Lygaeus pandurus</i> Scop. 15. <i>Myllocerus maculosus</i> Desb. 16. <i>Oxycarenus laetus</i> Kirby 17. <i>Pempheres affinis</i> Fst. 18. <i>Pericallia ricini</i> Fabr. 19. <i>Phycita infusella</i> Meyr. 20. <i>Platyedra gossypiella</i> Saund. 21. <i>Pseudococcus</i> sp. 22. <i>Sphenoptera gossypii</i> Cotes 23. <i>Sylepta derogata</i> Fabr. 24. <i>Tarache nitidula</i> F. 25. <i>Thrips tabaci</i> Lind.
Uttar Pradesh	<ol style="list-style-type: none"> 1. <i>Aphis gossypii</i> Glov. 2. <i>Chrotogonus</i> sp. 3. <i>Dysdercus cingulatus</i> Fabr. 4. <i>Earias fabia</i> Stoll 5. <i>Earias insulana</i> Boisd. 6. <i>Myllocerus maculosus</i> Desb. 7. <i>Oxycarenus laetus</i> Kirby 8. <i>Platyedra gossypiella</i> Saund. 9. <i>Sylepta derogata</i> Fabr.
West Bengal	<ol style="list-style-type: none"> 1. <i>Aphis gossypii</i> Glov. 2. <i>Dysdercus cingulatus</i> Fabr. 3. <i>Earias fabia</i> Stoll 4. <i>Earias insulana</i> Boisd. 5. <i>Oxycarenus laetus</i> Kirby 6. <i>Sylepta derogata</i> Fabr.

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I.C.C.C.—Indian Central Cotton Committee.

I.C.G.R.—Indian Cotton Growing Review.

I.C.A.R.—Indian Council of Agricultural Research.

CHAPTER V

SEED MULTIPLICATION AND DISTRIBUTION

The growth and health of any plant, as also its qualitative characters, depend fundamentally on the seed which produces it. The seed carries the characters of the parents ; and where a variety has been isolated for special characters, the purity of its seed has to be maintained in all further propagation so that the qualitative aspects for which it was evolved are preserved. While the plant breeders go on experimenting with different kinds of strains, evolved by either selection or hybridisation, the responsibility for the maintenance of purity of any given type in the field, must devolve on those who are directly connected with its cultivation, as farmers, extension workers or executives.

From time immemorial great care has been taken to preserve carefully the seed of the cultivated crops. Evidence of this is available in the finds from the archaeological excavations carried out in different countries. In fact, it is to the natural instinct of saving seed for the future that we owe the richness of our agricultural heritage. The spread of crops from their original habitats to distant areas, the slow and difficult process of acclimatizing them to their new environments, carried on from generation to generation, and the production of special strains and varieties when scientific methods were unknown, are but a few examples of the care and attention bestowed on seed propagation through the ages. The hypothesis of Dr. Hutchinson that cotton seed was carried to South America from Asia is a pointer to the painstaking labour through which the crop spread to remote areas.

In this chapter an account of the efforts made since the beginning of the present century for the multiplication and distribution of cotton seed in India on scientific lines is given. The work done in some of the other major cotton growing countries is also mentioned by way of comparison.

EARLIER WORK UNDER AGRICULTURAL DEPARTMENTS

Fletcher writing on the improvement of cottons of Bombay Presidency in the *Agricultural Journal of India*, as far back as 1906, said :

"If the cultivator's and dealers' honesty must, like Caesar's wife, be above suspicion, the following is put forward as an alternative to the usually accepted view of the method of displacement of Bani by Varadi. There is evidence tending to prove that in some districts the cultivation of Bani is more paying than that of Varadi, though the yield per acre of the latter is the greater. Suppose, therefore, that the cultivator of a district wishes to continue to cultivate Bani as a pure crop, he may only be able to raise a mixture through contamination of the seed at the gin. Suppose, further, for the sake of illustration, that a plant of Varadi produces twice the number of seeds of a plant of Bani. Then, if we have one plant of Varadi as a weed in a field of Bani, and this is not removed, the resulting

seed when sown will give two plants of Varadi to the acre of Bani, the following season four plants, and so on. The percentage of impurity would thus, if unchecked, increase from year to year in geometrical progression up to the point of complete substitution of the weed for the original crop. A cultivator may, thus, unconsciously allow Varadi to displace Bani in his fields, even though he knows that the latter would pay him better. If the cultivator had the knowledge and initiative required for the separation of the two varieties—not to the uninitiated very different from one another—there would, of course, be no possibility of his unconsciously decreasing his income in this way. Cultivators, however, as a rule, know much less of the varieties of cotton, than of such crops as sorghum, wheat and the like, the excellency or otherwise of the produce of which is more or less brought home to them very practically in their daily bread. On the above supposition as to the relative number of seeds produced by single plants of the two varieties, it is easy to show that it would take only 16 years to convert fields of Bani containing one Jari plant per acre into fields containing nothing but Jari. The supposition, however, assumes a greater disproportion between the fields of Jari and Bani than is ordinarily found. The following is a closer approximation in actual facts. Taking the rates of seed cotton to be Rs. 7 and Rs. 8·75 (per 80 lb.) for Jari and Bani, respectively, we see that the two varieties are equally paying to the cultivator if Bani yields 120 lb. of seed cotton per acre when Jari yields 150 lb. Of the 120 lb. of Bani, 75 per cent. or 90 lb. is seed and of Jari 68 per cent. or 102 lb. The ratio of the number of seeds produced by a single plant of Bani and Jari would seem, therefore, to be as 9 is to 10 and not as 1 to 2. The problem is, however, complicated by the fact that though single seeds are of equal weight in both cases, a greater number of seeds of Bani should probably be sown per acre than of Jari to secure the best results. It will be apparent that much more experiment is necessary before it can be stated that the cultivation of Jari is invariably more paying than Bani under the same set of conditions *when the produce in each case fetches its intrinsic value.*"

The above observations of Fletcher not only analyse the need for the maintenance of purity, but also indicate the trend which sets in if even a small impurity is allowed to remain and multiply itself unchecked. They also show the attention which cotton received from the Agriculture Departments from their very inception in the early years of this century.

In the report on the Progress of Agriculture in India for 1907-09, which is the first of its kind, it is stated that the distribution of seed of selected pickings from cultivators' fields had been in progress for more than four years in several Provinces, but without much result. The report goes on to say that this was hardly surprising, for such selection, while no doubt supplying sound seed was, properly speaking, no selection at all as the fields ordinarily contained many varieties mixed together. It was recognised that real improvement could be effected by isolating types and continuing plant-to-plant selection. The report mentions that this line of work was being followed at the Government Experimental Stations with encouraging results.

In 1908, eight cotton seed farms were maintained by private agencies under a guarantee from the Government against losses. Such farms had been in existence for the previous four years. They grew ordinary varieties of Bani and were situated in the districts noted for their high quality cotton. The seed of first and second pickings was purchased by the Department above the market rates for distribution. It was intended that in course of time when the selection at the experimental station proved successful, these farms would function as agencies for the distribution of improved strains of seed. It is stated that the ultimate object was to establish a number of such farms independent of the Department but receiving the assistance, when

required, for the provision of seed and trained staff for advice. But selection of cotton seed was in progress in the Punjab, Bengal and United Provinces. As a result of the work of introduction of superior indigenous varieties, there arose a demand for the introduction of Broach cotton in Dharwar district. This cotton was found to be superior to Local Kumpta variety, not only in quality but also apparently in quantity, yield per acre and lint percentage.

In 1907-08, 16,000 lb. of seed of Broach cotton from Navsari were sown in parts of Dharwar district, in addition to the seed of this crop grown locally in 1906-07. Attempts were also made to introduce Broach cotton under irrigation in the Deccan. Experiments, however, proved to be unsuccessful owing to faulty cultivation and irrigation. In Tinnevely district of Madras, Karunganni variety proved superior in both quality and yield to Uppam variety. Arrangements were, therefore, made by the Department to sell pure Karunganni seed sufficient to sow about 8,000 acres in 1907-08. This work was partly helped by a grant from the British Cotton Growing Association. The Madras Agriculture Department had also made successful efforts to improve the *ryot's* methods of cotton cultivation. Expert cultivators were sent for acquainting the growers with the use of the country drill and bullock hoe and for demonstrating the value of improved cultivation. Implements were supplied free and expert labourers were sent to help the growers. It is also on record that in the Central Provinces and Bengal, the cultivation of Buri cotton (an acclimatised variety of American type), which was found to give successful results, was extended. Arrangements were made during 1908-09 to secure a large quantity of seed for distribution. The variety was found to be a good cropper in areas of fairly heavy rainfall, yielded a higher percentage of good quality lint, and was comparatively resistant to wilt.

In 1909-10, the total quantity of selected cotton seed supplied to the cotton growers in Central Provinces was 1,23,500 lb. Of this, 43,000 lb. came direct from the Government Farms, particularly the Akola Farm. The remainder was supplied by private farms. It was reported that the economic difficulty in regard to the development of constant strains of improved seed was that an improved variety did not usually find a better market than cottons of ordinary quality. For an improved variety, though it was rated higher by the dealers, the cultivators could not secure the evaluated price owing to the absence of market for superior class of cotton. This coupled with the prevailing practice of mixing good seed with that of inferior varieties, presented a serious problem to the Agricultural Departments which were trying to effect improvement in the quality of cotton. As a result of the efforts of the Department of Agriculture, Madras, the cultivation of Karunganni variety in Tinnevely district had increased a great deal. In 1908-09, 1,40,000 lb. of pure seed were distributed by the Department as a result of which Karunganni predominated in the southern parts of Tinnevely district covering an area of about 18,000 acres. The cultivation of this variety proved more

remunerative as it was found to be superior in both yield and quality to the ordinary variety, Uppam. It is recorded that in 1910-11, the lint of some selected pedigree strain of Karunganni was valued at Rs. 380 per candy of 784 lb. as compared with the price of Rs. 345 for the ordinary field crop and Rs. 335 for ordinary Uppam. In the same year, about 1,20,000 lb. of Karunganni seed, sufficient to sow 14,000 acres, was sold at 43 depots. The tracts where such seed depots were opened had become pure Karunganni tracts. Seed depots were being opened at new places each year. It is reported that the cultivators kept the seed from their own crops for sowing, as better yields were obtained from this variety. In Kurnool area alone, 18,786 lb. of seed of white linted Tellapathi cotton were sold.

In 1910-11, the seed of two indigenous varieties, *roseum* and *malvence*, as well as of American Buri, totalling 1,34,000 lb., was distributed in Central Provinces and Berar from 36 seed farms in Berar and 6 in Central Provinces. In Madras, the cultivation of Cambodia cotton had gone up phenomenally under well irrigation, and during 1910-11 the produce was estimated at 33,000 bales valued at six million rupees. It was for the first time that a cotton of this type was spreading spontaneously on a large scale in India; and this extensive cultivation of the American cotton immensely increased the scope for improvement. In November, 1911, a Committee of the Board of Agriculture, while endorsing a note of the Inspector General of Agriculture on Cotton Investigation in India, made the following observations:

"The Members of the Department now in charge of cotton operations will have their hands quite full enough for some years together *with the task of distributing and maintaining the improved varieties* that have been so far developed or introduced. In almost all instances, cultivators already appreciate the good qualities of the improved types and (in the Central Provinces at least) are willingly paying enhanced rates for the seed. By remitting attention to the selection of seed year after year and by demonstration of improved methods of cultivation, the general standard of the crop is certain to rise steadily and in the immediate future, this work, accompanied by the evolution of new types by plant breeding, is all that the Departments can reasonably be expected to undertake."

These remarks sum up the results of the efforts made by the Departments of Agriculture in the multiplication and distribution of seed of improved varieties of cotton in the early years of this century.

It was during this period that the progress registered in the cultivation of selected seed of one variety was at its highest in Madras. The mixture of varieties grown was replaced by one variety, and the seed sown broadcast was drilled after the advantages of further interculturing had been demonstrated. This became particularly common in Tinnevely district of Madras State. Subsequently, with the establishment of ginning factories which ousted the old hand gins, it became difficult for the cultivators to get back pure seed, and the policy of seed distribution had, therefore, to be revised. This resulted in the area of the seed farms being restricted to about 400 acres which could be sown with the seed raised on the Government Farm at Koilpatti. The seed from these farms was sold to the cultivators and arrangements were made with the ginning firms to gin separately any consignment of this cotton brought

by them. This method was adopted in 20 village and there was large demand for selected seed at prices 40 per cent. above the rates of the ordinary seed. Work on similar lines was undertaken at Kurnool and Bellary. A noteworthy development at this time was the formation of two co-operative societies to promote the cultivation of cotton from seed selected by the Department.

Cambodia cotton was thoroughly established in the south of Madras Presidency and proved an exceedingly valuable introduction by the Department. It supplanted crops which on an average gave a profit of Rs. 30 per acre. In 1912, the acreage under Cambodia cotton was estimated at 60,000 acres yielding a premium of Rs. 180 per acre over the ruling price.

The cotton work in the Central Provinces was mostly devoted to the distribution of *roseum* seed through private cotton seed farms organised on a co-operative basis in Berar. These seed farms were grouped in co-operative unions of which only 14 were registered under the Act, while 18 were unregistered. The departmental supervision was concentrated on the central farms of the union, through which the seed from the Government Farm at Akola reached the private farms and ultimately the general public. There were 400 such private seed farms and about 1,76,00,000 lb. of seed were raised in 1914. This produced a crop of high ginning percentage worth rupees six more per acre than the local mixture. There was, therefore, a great demand for the seed, and the estimated area was two lakh acres in 1914. The Departments of Agriculture had to face several difficulties in the way of permanent improvement, the most important being: (i) organisation of seed distribution; (ii) supply of pure seed; (iii) prevention of adulteration in both seed and lint; and (iv) building up confidence of the buyers and spinners. It was, therefore, considered expedient to concentrate efforts on a comparatively small area and to establish a large Government Seed Farm with its own ginnery for demonstration and supply of seed. For this purpose it was decided to form suitable agricultural unions around the central farm. It was thought possible to cover the entire area with the improved type provided the unions grew only the improved cotton and undertook to gin it themselves, as was being done in Central Provinces.

It will thus be seen that year after year there was marked progress in the number of seed farms established and the improvements effected in the methods of seed distribution. In almost all the cotton growing provinces, selections from indigenous varieties were found to be superior to the prevailing mixtures either in quality or yield or both; and pending the evolution of better improved strains by purely scientific methods the introduction of the available forms was being pushed forward. The question of permanent improvement was, therefore, considered to be largely a matter of efficient organisation for controlling the seed supplied. In order to minimise the risk of adulteration, it was necessary to organise the work in such a way as to gradually replace the

country crop by the improved kind. The system of joint sale of cotton seed by the cultivators in a number of villages direct to the firms was considered promising from the point of view of profit to the cultivator and the spreading of the approved types. The mills were reported to be helping this movement.

In the Punjab, the work mostly related to the introduction of American cotton in the canal colonies. In 1914, over 2,000 acres were planted with seed of 4F cotton supplied from the Chenab Colony, and about 400 acres with seed secured from the Jhelum Colony. The produce fetched a premium ranging from Rs. 2·30 to Rs. 2·50 per maund over *desi* cotton. The question of effecting these improvements in other tracts was no doubt complicated and difficult. In the first place, control had to be exercised over the seed supplied, as otherwise, owing to various casues, it was liable to be mixed with seed of other varieties. Further, arrangements had also to be made in the initial stages to enable the growers to obtain adequate price.

Thus the policy to be adopted in the year 1917-18 for the distribution of cotton seed had to take into account factors like the suitability of the locality for the improved type and the high ginning percentage.

In the Punjab, Punjab-American, 4F, constituted about 72 to 80 per cent. of the total American crop in the Province. The area under American cotton increased from 2,15,000 acres in 1917 to 3,90,000 acres in 1918, and 80 per cent. of the crop was pure 4F. There were about eight cotton sales societies, functioning in Bombay and the chief benefits accruing from them were, honest weighments, fair price fixed by open competition among the dealers at auction, and no levy of improper cess or commissions.

WORK UNDER INDIAN CENTRAL COTTON COMMITTEE

In his report on the work of the Imperial Council of Agricultural Research concerning the application of science to crop production in India, Sir John Russel focussed attention on the need to bridge the gap between the experiment station and the cultivator. He was of the view that "by far the most important and most difficult task before the Agricultural Officers in India was to bridge the great gulf separating the Agricultural Experiment Stations and the few large scale farmers from the peasants who cultivated by far the largest proportion of the land." He continued that "it was not new science so much as fuller use of the existing science that was needed and the Council should order an inquiry to discover how best this could be done and to urge upon the proper authorities the need for taking all steps possible to this end. The Extension Officer should be recognised as a very important member of the staff and really competent men should be encouraged to continue at the work and be under no necessity to seek employment outside." He further said that "it should be impressed upon the workers at the experiment stations that they had a responsibility towards the cultivators and that they must not shut themselves up within the walls of the laboratory in the hope that somehow their work would

find practical application." One of the principal recommendations on the developmental side of the work of the Council was "to stimulate activities directed to the bridging of the gap between the experiment station and the cultivator and to arrange for the setting up of organisations for the multiplication and distribution of approved stocks of seeds, sets and fruit trees."

This was taken note of by the Indian Central Cotton Committee as early as in 1929. It was then felt that there was a lack of proper organisation for undertaking the work. In July, 1929, the Committee passed the following resolution at its 19th meeting with the object of remedying the lacuna:

"Resolution: That, in view of the extreme importance of the supply of seed of established improved varieties of cotton being made readily and cheaply available to the cultivators, the Indian Central Cotton Committee invites the State Governments and the Directors of Agriculture to submit proposals based on local requirements, whereby the Committee could assist by the provision of staff or funds or in any other way in the wider distribution of the seed of improved varieties of cotton to the cultivators."

In pursuance of this decision, the schemes for multiplication and distribution of improved seeds, which formed a real link between the farmer in the field and the research worker at the experiment station, were sanctioned by the Committee. The object of these schemes was to multiply a specific improved variety found suitable for a specific tract in a pure form under strict departmental supervision and to distribute the pure seed to as many cultivators as possible through departmental agencies. Of late, this work has been considerably intensified and now seed multiplication and distribution schemes cover practically all the latest improved strains under cultivation. The importance that the Committee has attached to this work can be gauged from the fact that so far an expenditure of Rs. 37·5 lakhs has been incurred on it and the present annual expenditure is Rs. 1·6 lakhs. During the past 27 years, the Committee has financed 58 schemes that have been completed and continues to finance 22 fresh schemes.

The aim of the Indian Central Cotton Committee has always been to supplement and not to supplant the work of the Agricultural Departments in the cotton growing States. Grants are made by the Committee for the multiplication and distribution of the improved varieties of cotton. The expenditure on seed multiplication and distribution schemes is divided into: (i) cost of staff; and (ii) incidental charges. The Committee bears either the cost of staff or the incidental charges, whichever is less, but not both.

Seed schemes are sanctioned by the Committee for periods not exceeding five years in the first instance, but they may be extended for a further period of five years on condition that: (i) the Committee's share of expenditure in the second period does not exceed 75 per cent. of either the pay of the staff or incidental charges, whichever is less; and (ii) the State Government concerned contributes not less than the sum spent by it during the original period of the scheme.

After a seed multiplication and distribution scheme has been in operation for a period of 10 years, the contribution of the Committee during the succeeding five years is limited to 30 per cent. of the cost of staff or incidental charges, whichever is less, subject to a maximum of 15 per cent. of the total cost of the expenditure on the scheme during the extension period.

All schemes, before approval, are subjected to a thorough examination at various stages, first by the Extension Sub-Committee, then by the full Agricultural Research Sub-Committee, and finally by the Indian Central Cotton Committee; and it is only after such scrutiny that a scheme is finally recommended to the Government of India for sanction.

Concurrently with the comparative tests on the cultivators' fields, demonstration plots for the new improved variety are set up each year in the tract deemed suitable for its growth. Each demonstration plot is half to one acre in size, depending upon the availability of land, and is bounded on either side by a similar plot of the local variety. The crop in the demonstration plots is grown by the cultivators themselves and receives the same treatment as is normally given to the local variety. The harvesting is done in the presence of the officials of the Agricultural Departments, and yields are determined for both the improved and local varieties. The extensive cultivation of the improved variety follows as a natural sequence once the growers are convinced of its superiority over the local type.

The ultimate criterion of the success of a new variety is the higher monetary return it brings to the cultivator. This higher income may be due to the higher yield per acre or the higher selling price, or both. It varies from year to year. The premium fetched by the various improved varieties during 1956-57 season is given below in Table 46.

TABLE 46. PREMIUM FETCHED BY THE IMPROVED VARIETIES

Variety	Premium
1. Virnar (Khandesh Tract)	.. Rs. 20 for certified over non-certified Virnar
2. Vijalpa (Surat Tract)	.. Rs. 40 per candy for agmark over trade variety
3. Digvijay (Middle Gujerat)	.. Certified Digvijay seed cotton Rs. 8 to Rs. 12 per <i>bhar</i> (960 lb.)
4. Kalyan (North Gujerat)	.. Rs. 10 per bale of lint for Reserved Area produce over produce of General Area
5. a. Jayadhar	.. Rs. 20 to Rs. 30 per <i>nag</i> . of 1344 lb. of certified <i>kapas</i>
b. Laxmi	.. Rs. 50 to Rs. 70 per <i>nag</i> of 1344 lb. of certified <i>kapas</i>
6. H. 420	.. Rs. 3 per <i>khandi</i> of <i>kapas</i> (784 lb.)
7. Buri 0394	.. Rs. 19 per <i>khandi</i> of <i>kapas</i> (784 lb.)
8. No. 91	.. Rs. 71 per <i>khandi</i> of <i>kapas</i> (784 lb.)
9. Gaorani 12	.. Rs. 3.50 to Rs. 4.50 per maund (82-2/7 lb.) of <i>kapas</i> over bulk Gaorani 12
10. Gaorani 6	.. Rs. 2.50 to Rs. 5 per maund (82-2/7 lb.) of <i>kapas</i> over bulk Gaorani 6
11. 2204 (Daulat)	.. Rs. 20 per <i>khandi</i> of <i>kapas</i>
12. Indore 1	.. Rs. 4 per maund (80 lb.) of <i>kapas</i>
13. Ganganagar 1	.. Re. 1 to Rs. 5 per maund of <i>kapas</i>
14. Pratap (Saurashtra)	.. Rs. 2 per Bengal maund (80 lb.) of <i>kapas</i>

continued

Variety	Premium
15. Kalyan (Saurashtra)	.. Rs. 3 per Bengal maund (80 lb.) of <i>kapas</i> (Bolls with seed cotton intact)
16. 35/1	.. Re. 1 to Rs. 2 per maund of <i>kapas</i>
17. 320F	.. Rs. 1.25 per maund of <i>kapas</i>
18. Karunganni 2	.. Rs. 30 per acre
19. M.C.U.2	.. Rs. 65 per acre
20. M.C.U.1	.. Rs. 55 per acre
21. Karunganni 5	.. Rs. 40 per acre
22. M. A. 5	.. Rs. 50 per bale of 392 lb. lint
23. Westerns 1	.. Rs. 30 per bale of 392 lb. lint
24. Selection 69	.. Rs. 15 per bale of 392 lb. lint

SEED MULTIPLICATION AND DISTRIBUTION IN STATES

The methods of seed multiplication and distribution in various States are intimately interlinked, and have been devised with the object of maintaining the purity of the seed of the improved varieties and facilitating rapid and systematic distribution of pure seed.

Whatever be the system of distribution, the maintenance of purity is achieved by strict departmental supervision at different stages of seed multiplication. After the release of a new variety, the breeder multiplies the seed by sowing self-fertilised seeds obtained from the experimental plot on an area of an acre or two known as the 'Nucleus Plot'. The 'selfed' seed for sowing in this plot is usually obtained from selected plants possessing true morphological, technological and agricultural characters of the variety. The flowers produced in the nucleus plots are again selfed. The selfing of flowers is done either by fixing galvanised iron rings or by twisting a tuft of lint dipped in a paste of clay over unopened flower buds. To distinguish the boll developing from a selfed flower from that of a non-selfed one, either a ring or a tuft of lint is fixed around the flower stalk. During harvest, the selfed bolls are picked separately and only the seeds obtained from these are utilised for further multiplication.

The self-fertilised seeds obtained from the nucleus plot are then multiplied on the Government Farms under the immediate supervision of the technical staff, and the entire area is systematically rogued by removing all the off-types. The seeds obtained from the multiplication plot in the Government Farm are grown at what are known as the 'Inner Seed Farms' or the 'Reserved Area'. These are arranged on selected cultivators' fields who bind themselves to: (i) grow the crop under departmental supervision; (ii) remove the off-types from the crop; (iii) allow the ginning of the produce under departmental supervision; and (iv) sell the entire seed material obtained from the area back to the departmental agencies. The seed from the inner reserved area is then distributed by the Department to what are known as the 'Outer Reserved Area' or the 'Outer Seed Farms' where seed is multiplied under conditions similar to those for the inner seed farms. It is in the disposal of the seed of the outer seed farms or reserved area to the cultivators at large that the help of

approved stockists or co-operative cotton sale societies is enlisted. Thus at every stage, from the production of the nucleus seeds of an improved variety to its final distribution to the cultivators on a large scale, strict departmental supervision is exercised which ensures the maintenance of purity. This is the general system followed in the States of Bombay, Madras, Madhya Pradesh and Mysore. In Hyderabad, however, a slightly different system is in vogue. The sowing of the crop, the disposal of the produce and the ginning of *kapas* are supervised by the Agriculture Department. After ginning, the seed is stocked in bags which are suitably labelled. This seed is distributed in the following year in a *compact block* of about 2,000 acres and the process is repeated in the succeeding seasons in a gradually expanding area. Roguing of the crop in areas reserved for securing seed for general sowings is done by the staff of the Agricultural Department and contamination of seed in ginneries is guarded against by governmental supervision of the ginning operatives. To prevent mixing and to guarantee the purity of the produce, the Department inspects the standing crops in the fields, licenses petty buyers in villages, supervises ginning, packs the seed in bags, and labels them before affecting distribution.

The arrangements made for the marketing and handling of the Gaorani variety from the field to the factory as part of the seed distribution work are described below:

It is said that normally it takes about nine years of study before a strain can be finally selected and recommended to the growers for cultivation. The variety is then tested on the cultivators' fields in several villages against the local variety. The crop in the demonstration plots is grown by the cultivators themselves, and receives the same treatment as is normally given to the existing variety. The harvesting is done in the presence of the officials of the Agriculture Department, and yields are determined for both the improved and local varieties. The extensive cultivation of the improved variety after it has convinced the grower of its superiority to local cotton follows as a natural sequence.

With a view to maintaining the supply of pure seed expanding gradually from a small plot of the 'selfed' seed at the cotton research station to the entire tract growing the variety, every year, one acre of land at the Government Farm is grown from the 'selfed' seed obtained from the nucleus plot at the research station. The crop in the latter plot is raised from the 'selfed' seed of such of the 250 random selected plants as possess the true vegetative, floral, seed, ginning and fibre characters of the variety. The 'selfing' is thus carried out in the usual manner by fixing galvanised iron rings over large sized unopened buds so that the boll developing from the selfed flower is easily recognizable.

The seed obtained from the selfed seed plot is planted on 15 to 20 acres at the Government Farm in the succeeding season. The 'off-type' plants, if any, are removed from the resulting crop, and the entire produce is ginned at

the Government Farm under strict supervision. The seed from the plot is taken to a selected village where the annual area planted to cotton is about 200 acres and which is situated near a ginning factory. The sowing of the crop, the disposal of the produce, and the ginning of *kapas* are supervised by the Department of Agriculture. After the *kapas* is ginned, the seed is stocked in bags which are suitably labelled. This seed is distributed in the following year in a compact block of about 2,000 acres, and the process is repeated in succeeding seasons expanding the area about 10 times each year. Rouging of the crop in areas reserved for securing planting seed is done by the staff of the Agricultural Department and contamination of seed, at the ginneries is prevented by governmental supervision of the ginning and pressing of the entire produce. The area reserved for pure seed in the fifth year is generally split up into several parts and is located in different places. This not only facilitates extensive distribution of seed, but also minimises the risks of crop failure due to vagaries of rainfall. The seed renewal method described above takes nearly five years to supply pedigree seed for about two lakh acres. Though the rate of seed multiplication increases generally ten times at every stage, it may vary, depending on the availability of seed and variations in seasonal conditions. Thus, usually in areas subjected to wide variations in rainfall, the rate of multiplication of a new variety has varied from five to ten times. The urgency of seed multiplication has been greatly stressed in the case of one of the latest introductions, the Sea Island 'Andrews' variety, in an area which has not grown cotton on a commercial scale in the past. It has been possible in this tract to increase the rate of multiplication to 25 times by intensive propaganda and complete utilisation of all available seed. This rate of multiplication is an exception to the general accepted rate in the States. The control of seed once established continues to work fairly smoothly year after year. It is only in years of extensive failure of crops due to scarcity of rain that a breakdown may be apprehended. However, this catastrophe might be minimised by growing annually a part of the pedigree seed on a small area under irrigation.

In the former Hyderabad State, the Government purchased every year pure Gaorani seed worth over a lakh of rupees for distribution on *taccavi* which facilitated greatly the control of seed supply. The cost of the seed was paid by the cultivators over a period of three years. The loan was free of interest in the first year, and carried six per cent. interest in the remaining two. The amounts due on this account were recovered by the Revenue Authorities at the time of collection of land revenue.

The control of seed of Gaorani 6 as described above was in vogue in the former Hyderabad State for several years.

The Hyderabad Cotton Cultivation and Transport Act empowered the Hyderabad Government to prohibit, in a previously notified part of the Gaorani Protected Area, the growing of a variety not approved by the Department of Agriculture. This power has not been utilised so far because the new

variety has on its own merits proved itself acceptable to cultivators of the area selected for it.

The various stages of seed multiplication followed in different States are indicated below.

Bombay :

1. Cotton seed multiplication in South and Middle Gujerat and Khan-desh is done in the following five stages:

- (i) Nucleus Plot.
- (ii) Government Farm.
- (iii) Inner Reserved Area (selected growers).
- (iv) Outer Reserved Area (villages at group centres).
- (v) General Cultivators.

2. In North Gujerat, multiplication is done in seven stages:

- (i) Nucleus Plot.
- (ii) Inner Pedigree Area.
- (iii) Outer Pedigree Area
- (iv) Inner Reserved Area.
- (v) Outer Reserved Area.
- (vi) Controlled Seed.
- (vii) General Cultivation.

Punjab :

Seed multiplication is done in six stages:

- (i) Selfed Seed Plot.
- (ii) Cotton Breeding Farm.
- (iii) Departmental Seed Farm
- (iv) 'A' Class Registered Growers.
- (v) 'B' Class Registered Growers.
- (vi) General Cultivation.

Madhya Pradesh :

Seed multiplication is done in five stages :

- (i) Breeders' Plot.
- (ii) Government Farm.
- (iii) Seed Farm's Plots.
- (iv) Selected Cultivators' Fields.
- (v) General Cultivation.

Uttar Pradesh :

Seed multiplication is carried on in five stages :

- (i) Nucleus Plot on a Government Farm.
- (ii) Multiplication Plots at Government Farms.
- (iii) Selected Growers in the Districts.
- (iv) Extended Area of Selected Growers.
- (v) General Cultivation.

Madras :

Seed multiplication is done in five stages:

- (i) Nucleus Plot on Breeding Station.
- (ii) Agricultural Fram.
- (iii) Inner Seed Farms.
- (iv) Outer Seed Farms.
- (v) General Cultivation.

Mysore :

Seed multiplication is done in five stages :

- (i) Nucleus Plot on a Government Farm or a Subvention Farm.
- (ii) Bulk Plot on a Government Farm or a Subvention Farm.
- (iii) 'A' Grade Seed Farms.
- (iv) 'B' Grade Seed Farms.
- (v) General Cultivation.

Table 47 shows the pattern of seed multiplication work in the States.

It will be seen that the number of stages of multiplication as well as the nomenclature employed for indicating them varies from State to State. Thus, within the same State, as for instance in Bombay, the second stage seed is multiplied on the Government Farm ; in Khandesh and South and Middle Gujerat tracts, it is designated as an inner pedigree area without mentioning the locality where it is multiplied in North Gujerat. In most States, the stages of multiplication are only five, and the sixth stage is more or less the general area, while in North Gujerat seed multiplication spreads over six stages and general cultivation forms the seventh stage. It seems, therefore, necessary that a certain uniformity in the number of stages and nomenclature used should be brought about so that the multiplication and distribution of pure seed is standardised.

As will be explained later, the Indian Central Cotton Committee has already appointed a Sub-Committee to examine the question in detail.

PARTITION AND AFTER

After the Partition, India lost 9·8 lakh bales of cotton which were being produced in areas ceded to Pakistan. The imports increased, greatly intensifying the foreign exchange difficulties. The internal demand was also expanding rapidly, and it was obvious that the crisis threatening the industry could be averted by stepping up the production. In 1949, the Indian Central Cotton Committee drew pointed attention of the Government of India to the serious situation created by the partition of the country, diversion of cotton area to other crops, and the devaluation of currency which had resulted in considerable increase in the rupee value of foreign cotton. It, therefore, stressed the need for raising the annual production by about a million bales in order to meet the internal requirements of the textile industry and allow a fair amount of surplus for export.

TABLE 47. PATTERN OF SEED MULTIPLICATION WORK IN THE DIFFERENT STATES

State	1st stage	2nd stage	3rd stage	4th stage	5th stage	6th stage	7th stage	Remarks
Bombay (South and Middle Gujarati and Khandesh tract)	Nucleus plot	Government Farm	(a)	Inner reserved area	Outer reserved area	(a)	General cultivation	Takes 5 years to reach general cultivation
Bombay (North Gujarati)	Nucleus plot	Inner pedigree area	Outer pedigree area	Inner reserved area	Outer reserved area	Controlled seed	"	Takes 7 years to reach general cultivation
Punjab	Selfed seed plot	Cotton Breeding Farm	Departmental seed Farm	'A' class registered growers	'B' class registered growers	(a)	"	Takes 6 years to reach general cultivation
Madhya Pradesh	Breeders' plots	Government Farm	Seed Farm's plot	(a)	Selected cultivators' fields	(a)	"	Takes 5 years to reach general cultivation
Uttar Pradesh	Nucleus plot on Government Farm	Government Farm	(a)	Selected growers in districts	Extended area of selected growers	(a)	"	Takes 5 years to reach general cultivation
Madras	Nucleus plot on Breeding Station	Agricultural Farm	(a)	Inner seed Farms	Outer seed Farms	(a)	"	Takes 5 years to reach general cultivation
Mysore	Nucleus plot on Government Farm	Bulk plot on Government Farm	(a)	'A' grade seed Farms	'B' grade seed Farms	(a)	"	Takes 5 years to reach general cultivation

(a) Stages omitted.

In May, 1950, the Government of India in consultation with the various State Governments prepared detailed plans and sanctioned schemes for individual States for increasing the cotton production by six lakh bales in 1950-51 as compared to 1949-50. To achieve this objective, the following steps were taken early in 1950.

1. All legislative and executive restrictions on the growing of cotton were removed.
2. Additional irrigation facilities for growing cotton were provided, wherever possible.
3. Land revenue remission was granted in respect of additional land brought under cotton cultivation.
4. A guarantee was given to the State Governments to make good the short fall in foodgrains caused by the diversion of land from food crops to cotton.
5. Supplies of improved seeds and fertilisers were made available on a large scale at subsidised rates and, wherever necessary, funds were loaned to the State Governments for their bulk purchases.
6. Special staff was appointed in all the cotton growing States for the execution of the plan.
7. The basic ceiling prices of all varieties of cotton for the season 1950-51 were increased by Rs. 150 per candy (784 lb. of lint) in comparison with the prices fixed for them in the previous year.

All the above measures, in general, excepting the third item, were continued in the subsequent five years and included in the First Five-Year Plan for cotton in 1951-52. Concurrently, the Indian Central Cotton Committee made vigorous efforts to enable the cultivator to grow better quality cotton by providing liberal grants to the States for the multiplication and distribution of seed of improved varieties and evolving still better varieties.

FIRST FIVE-YEAR PLAN

The measures adopted under the plan for increasing the production of cotton in the various States included the following :

1. Expansion of cotton area by : (i) reclamation of waste and fallow lands; (ii) replacement of food and other crops ; and (iii) growing cotton as a second crop.
2. Intensive cultivation by : (i) provision of irrigation facilities ; (ii) intercropping cotton with other crops ; (iii) use of improved seed ; (iv) application of manure and fertilisers ; (v) provision of adequate plant protection measures ; and (vi) adoption of improved cultural methods.
3. Propaganda and technical advice to cotton growers.

The targets of area and production of cotton fixed for the various States for 1955-56, the final year of the First Five-Year Plan, compared with the actuals for 1950-51, the basic year of the plan, are shown below in Table 48.

TABLE 48. TARGETS OF AREA AND PRODUCTION

State	Area (thousand acres)		Production (thousand bales)	
	Actual 1950-51	Targets 1955-56	Actual 1950-51	Targets 1955-56
Bhopal	46	65	4	10
Bombay	3,487	4,000	803	1,078
Hyderabad	2,418	3,350	260	460
Madhya Bharat	1,586	1,700	219	311
Madhya Pradesh	2,776	3,750	510	680
Madras	1,730*	994	348*	320
Andhra				
Mysore	108	410*	33	89*
Pepsu	266	370	175	255
Punjab	447	650	196	346
Rajasthan	350	425	114	164
Saurashtra	1,075	1,100	216	222
Uttar Pradesh	106	240	45	85
Other States	161	160	48	49
Total	14,556	18,000	2,971	4,229

* Figures for Bellary district are included in Mysore State in 1953.

It will be seen from the above table that the increase in cotton production in the country visualised under the First Five-Year Plan was 12.58 lakh bales or 42 per cent. over that in 1950-51.

The introduction of improved cotton strains from time to time brought about great improvement in the quality of Indian cotton as may be seen from Table 49.

Indian cotton which in the international market had been more or less synonymous with a short staple cotton, has changed its character in that the production of short staple has been reduced to about 17 per cent. of that of the long and medium staples (Fig. 41).

An idea of the increase in cotton area and production between 1950-51 and 1955-56 may be had from Table 50.

Both the cotton area and production increased from 14.5 million acres and 29.10 lakh bales in 1950-51 to 18.68 million acres and 42.27 lakh bales, respectively, in 1954-55, thereby achieving the targets of 18.0 million acres and 42.29 lakh bales fixed under the First Five-Year Plan, an year ahead of the schedule. Cotton area registered further increase during the 1955-56 season and the total area and production was estimated at 19.98 million acres and 40.01 lakh bales, respectively. The production during

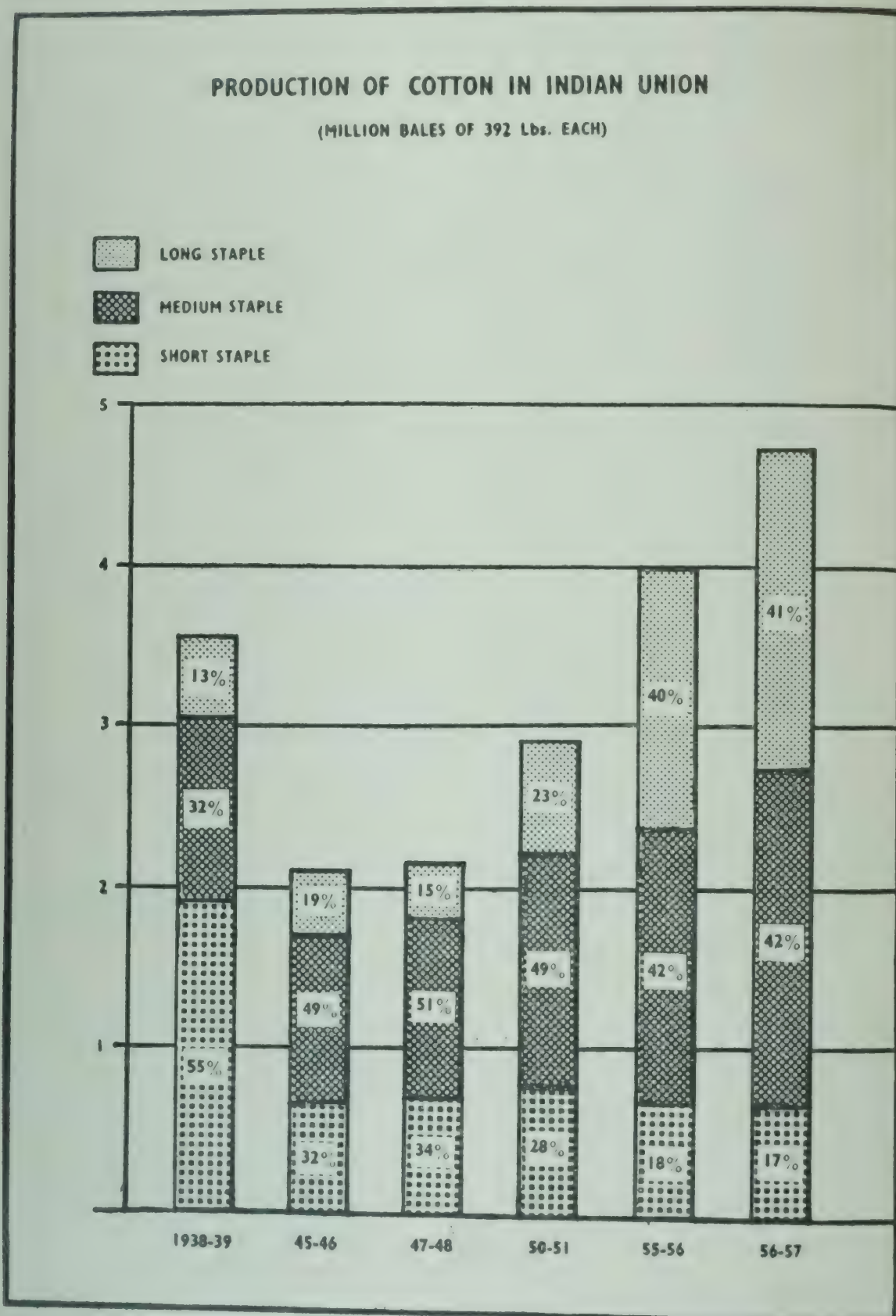


Fig. 41. Production of Cotton Under Different Staple Length Groups

TABLE 49. PRODUCTION OF COTTON UNDER DIFFERENT STATES

Year	Long staple (thousand bales of 392 lb.)	Medium staple	Short staple	Total
1938-39	469	1,179	2,012	3,660
1939-40	511	1,115	2,107	3,733
1940-41	627	1,302	2,542	4,471
1941-42	657	1,648	2,172	4,479
1942-43	666	1,459	1,030	3,155
1943-44	818	1,766	1,121	3,705
1944-45	429	1,128	665	2,222
1945-46	413	1,068	686	2,167
1946-47	405	1,008	755	2,168
1947-48	319	1,124	745	2,188
1948-49	322	889	556	1,767
1949-50	550	1,332	746	2,628
1950-51	684	1,448	839	2,971
1951-52	918	1,223	992	3,133
1952-53	905	1,395	831	3,131
1953-54	1,442	1,651	872	3,965
1954-55	1,529	1,908	790	4,227
1955-56	1,610	1,692	699	4,001
1956-57	1,938	2,007	778	4,723

TABLE 50. AREA AND PRODUCTION DURING FIRST FIVE-YEAR PLAN

Year	Area (thousand acres)	Production* (thousand bales)
1950-51 (Base Year)	14,536	2,910
1951-52	16,101	3,133
1952-53	15,713	3,194
1953-54	17,265	3,944
1954-55	18,684	4,227
1955-56	19,978	4,001

* Revised figures.

1955-56 decreased compared to the previous season, due to the unfavourable weather conditions prevailing during the later period of the crop growth. It is noteworthy that the increase was mostly in respect of the long and medium staple varieties. In 1950-51, the production of long, medium and short staple varieties was 6.84, 14.48 and 8.39 lakh bales forming 23, 49 and 28 per cent., respectively, of the total crop. The corresponding figures of 1955-56 were 16.10, 16.92 and 6.99 lakh bales constituting 38, 45 and 17 per cent., respectively. Thus, compared to 1950-51, the total production increased by 35 per cent. in 1955-56, while the production of long and medium staples increased by 123 per cent. and 23 per cent., respectively. Moreover, the loss of about 10 lakh bales of medium and long staple cotton grown in the

territories included in Pakistan was fully made up by increase in the indigenous production. The other noteworthy features in the improvement brought about are:

1. The area under improved varieties registered an increase of about 84 per cent., from 7.2 million acres in 1950-51 to 13.6 million acres in 1955-56.
2. The area under irrigated cotton increased from 1.1 million acres in 1950-51 to 1.9 million acres in 1955-56.
3. About 27,000 tons of ammonium sulphate were used by the cultivators annually.
4. Cultivators have, in general, begun to understand the advantages of sowing the crop at right time, with right spacing, with right doses and time of application of manure and have also adopted improved cultural methods like line sowing of crop and adoption of plant protection measures against pests and diseases.

Table 51 records the targets and achievements in respect of area and production of cotton during the First Five-Year Plan Period (Figs. 42 and 43) :

TABLE 51. TARGETS AND ACHIEVEMENTS DURING FIRST FIVE-YEAR PLAN

Year	Target	Achievement
(thousand acres)		
Area		
1950-51 (Base year)		14,536
1951-52 } 1952-53 }	Not fixed	{ 16,101 15,713
1953-54	17,075	17,265
1954-55	17,542	18,684
1955-56	18,000	19,978
<hr/>		
Year	Target	Achievement
(thousand bales of 392 lb. each)		
Production		
1950-51 (Base year)		2,910
1951-52	3,229	3,133
1952-53	3,481	3,194
1953-54	3,729	3,944
1954-55	3,979	4,227
1955-56	4,229	4,001

WORK UNDER SECOND FIVE-YEAR PLAN

The measures adopted for increasing cotton production under the First Five-Year Plan are being continued in the Second Plan Period also. The target of production is 65 lakh bales which has been fixed after taking into

AREA UNDER COTTON IN INDIAN UNION
FIRST FIVE YEAR PLAN
TARGETS AND ACHIEVEMENTS (MILLION ACRES)

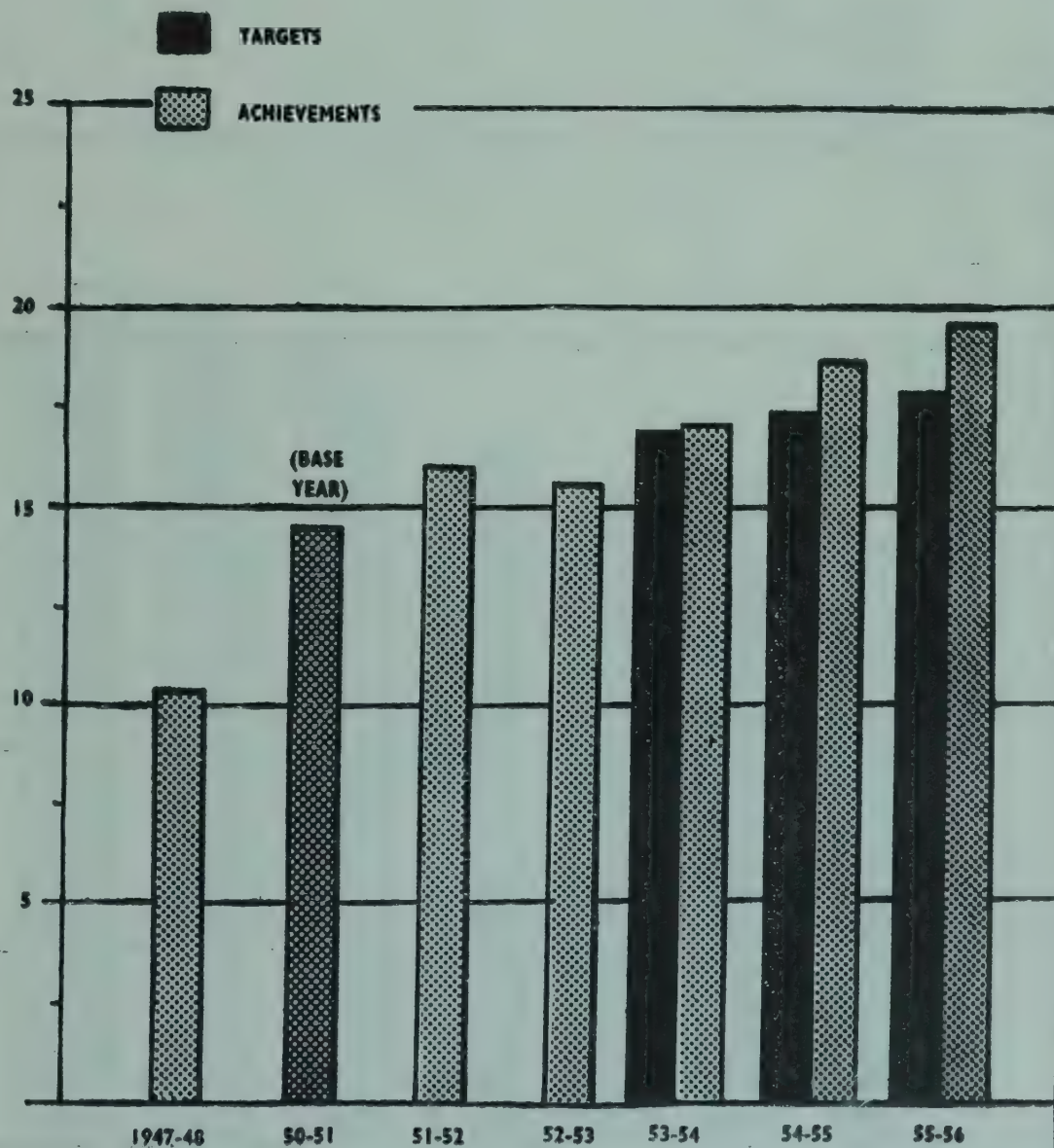


Fig. 42. Area Under Cotton During First Five-Year Plan

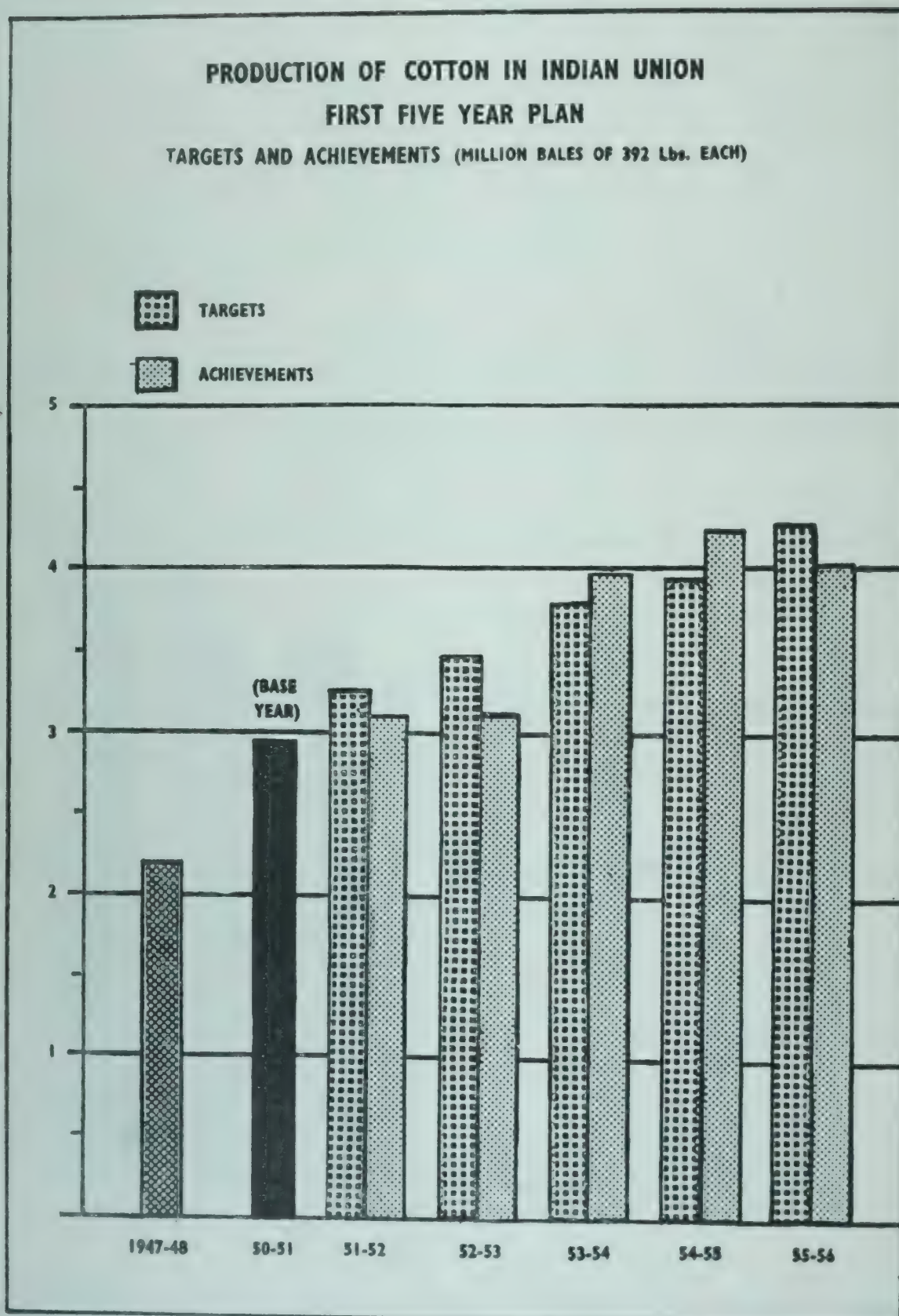


Fig. 43. Production of Cotton During First Five-Year Plan

account the increased target of textile production and allowing for exports, extra-factory consumption and the need for a comfortable carryover. The Statewise distribution of this target is given in Table 52 (Fig. 44).

TABLE 52. STATEWISE DISTRIBUTION OF TARGETS UNDER SECOND FIVE-YEAR PLAN

State	Target of cotton production (thousand bales of 392 lb. each)
Punjab	1,250
Rajasthan	290
Uttar Pradesh	110
Madhya Pradesh	567
Bombay	2,934
Mysore	670
Madras	450
Andhra Pradesh	165
Orissa	30
Other States	43
Total	6,500

The Indian Central Cotton Committee has sanctioned a total of 80 seed multiplication and distribution schemes since its inception, of which 58 have terminated and 22 are in operation (1957-58). The schemes which terminated related to multiplication and distribution of the following improved varieties (Fig. 45).

Bombay State : Jayawant, Gadag 1, 1027 A L. F., Banilla, B.D.8, Jarila, Selection 1A, Wagotar, Suyog, B.9, V.34, Buri 107, M.54, Dharwar 1, Parbhani-American.

Madras : Co.2, Co.3, Co.4.

Andhra Pradesh : Westerns 1, Cocanadas 1.

Mysore : Selection 69, M.A.5., Jayadhar, Laxmi.

Punjab : L.S.S., 216F.

Uttar Pradesh : C.402, Perso-American.

The earlier varieties for which seed was multiplied under the schemes financed by the Committee were evolved either under the research schemes of the Committee or by the State Departments of Agriculture. Thus Jayawant, Gadag 1, 1027 A L. F., Banilla, B.D.8, Selection 1A, Suyog, B.9,

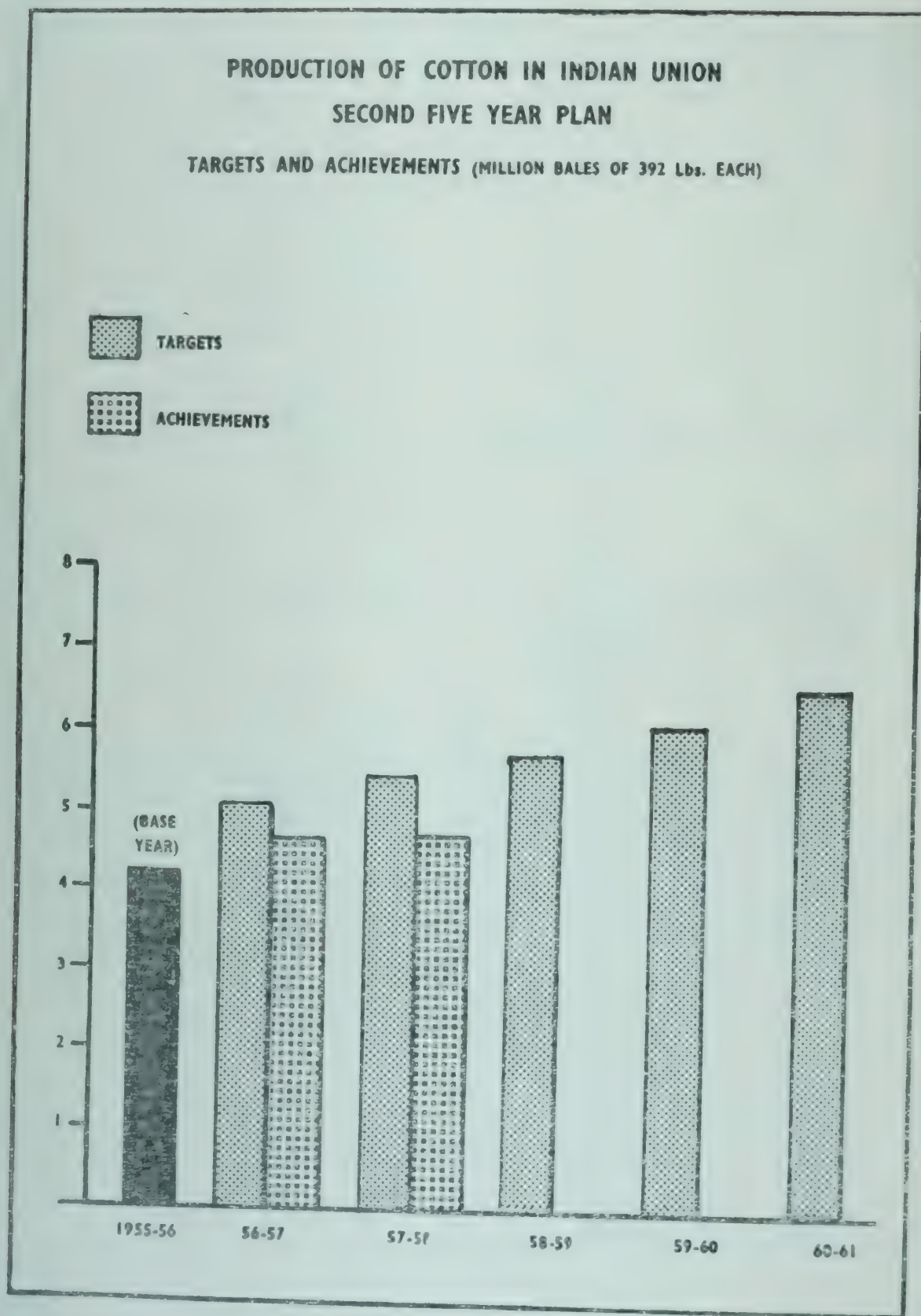


Fig. 44. Production of Cotton During Second Five-Year Plan

Dharwar 1 of Bombay; Co.2, Co.3, Co.4. of Madras; Westerns 1 of Andhra; Selection 69, Jayawant and Jayadhar of Mysore; L.S.S. of the Punjab; and C.402 of Uttar Pradesh, were evolved by the respective State Departments of Agriculture. Other types like Wagotar, V.434, Buri 107, Parbhani-American, Cocanadas 1, M. A. 5, Laxmi, 216F and Perso-American were evolved under the schemes of the Committee.

In the earlier years, the main object was to substitute the poor quality bulk grown by the cultivators from bazar seed with improved types having better yield and more remunerative economic characters.

The seed multiplication and distribution schemes now in operation relate to the following varieties of cotton.

Bombay State : 197/3, 2087, Kalyan, Vijay, H.420, Buri 0394, No. 91, Gaorani 12, 2204 (Daulat), Gaorani 6, Pratap, 170-Co.2.

Madras : M.C.U.1, M.C.U.2, K.2, K.5.

Punjab : 320F, H.14.

Uttar Pradesh : 35/1.

Rajasthan : Indore 1.

Madhya Pradesh : D. 48-154 (Maljari).

The area covered by the improved varieties as a result of the Committee's schemes for multiplication and distribution of improved cotton varieties in the different cotton growing tracts during 1955-56 is given in Table 53 (Fig. 46).

TABLE 53. AREA COVERED BY IMPROVED VARIETIES IN DIFFERENT COTTON GROWING TRACTS

State	Tract	Variety	Area pro- posed to be ultimately covered by improved variety (acres)	Area covered during 1955-56 (acres)	Area yet to be covered (acres)
Punjab	Ferozepur (Ludhiana) Jullundur and Amritsar districts	320F	3,80,000	3,48,655	31,345
Bombay	Khandesh tract	197/3 (Virnar)	10,00,000	9,56,993	43,007
	Surat tract	2087 (Vijalpa)	6,70,000	5,88,000	82,000
	Middle Gujerat tract	Vijay (Digvijay)	8,61,372	8,61,372	Nil
	North Gujerat tract	Kalyan	5,50,000	5,50,000	Nil
	Bombay-Karnatak tract	Jayadhar	6,00,000	6,07,308	Nil
		Laxmi	6,00,000	5,38,433	61,567

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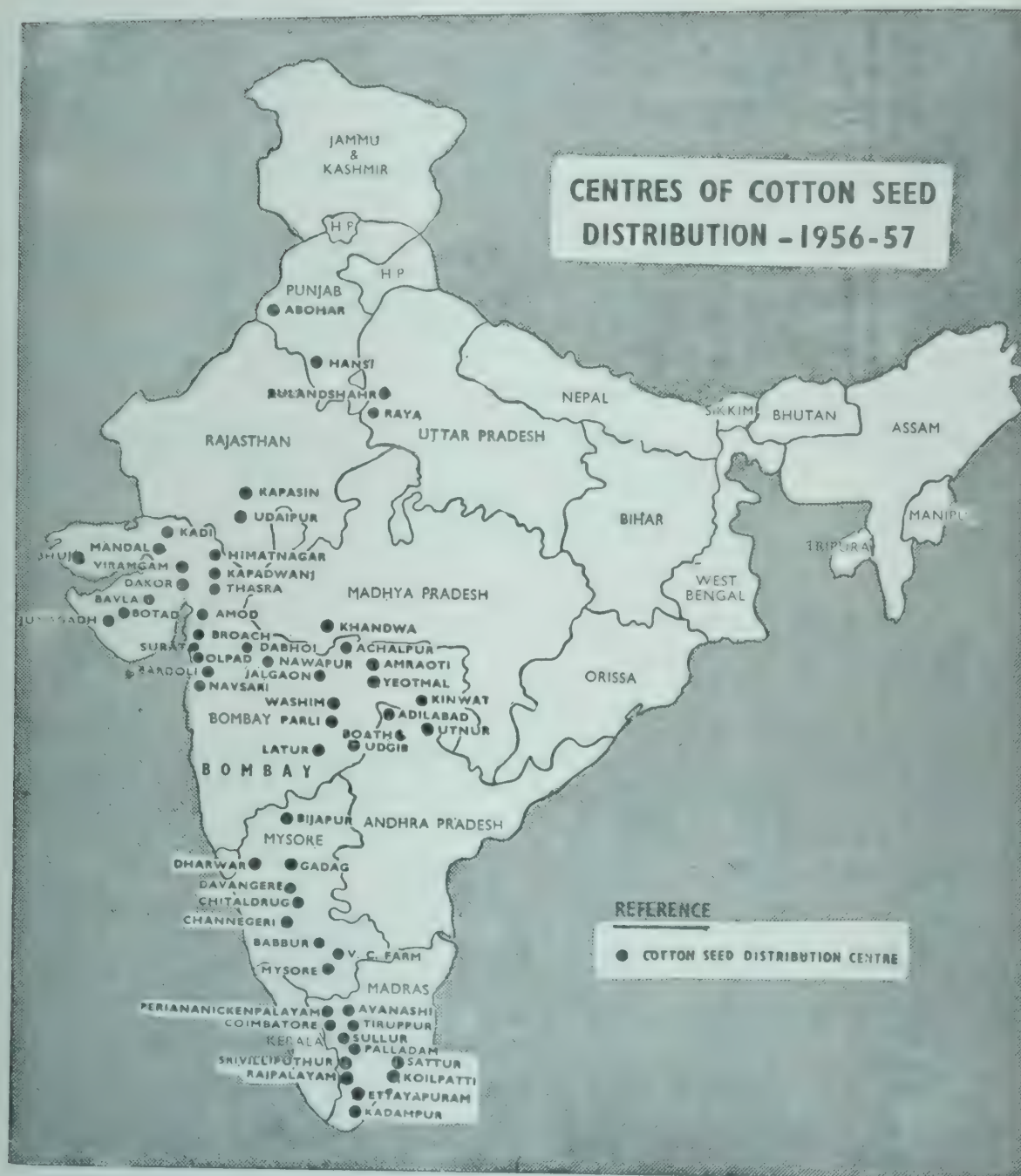


Fig. 45. Centres of Cotton Seed Distribution

State	Tract	Variety	Area pro- posed to be ultimately covered by improved variety (acres)	Area covered during 1955-56 (acres)	Area yet to be covered (acres)
Madras	Tirunelveli, Ramnatha- puram and Madurai dis- tricts area) (summer cropped area)	K.2	3,93,000	2,65,000	1,27,800
		M.C.U.2	65,090	66,500	Nil
	(winter cropped area)	M.C.U.1	2,00,000	1,04,900	95,100
	Coimbatore, Madurai, Tiruchirapalli and Salem districts	K.5	1,87,700	1,16,437	71,263
Madhya Pradesh	Amravati, Yeotmal, Akola, Nimar, Nagpur and Wardha districts	H.420 (Rukmini)	27,46,712	7,28,061	20,13,651
		Buri 0394	4,05,988	1,91,970	2,14,018
	Nagpur-Wardha tract Buldana district	No. 91	1,22,500	1,365	1,21,135
		M. 5. A. (Malini)	1,20,000	19,175	1,00,825
Hyderabad	Osmanabad, Bidar and Bhir districts	Gaorani 12	3,00,000	2,79,034	20,966
	Parbhani district	2204 (Daulat)	5,00,000	3,800	4,96,200
Rajasthan	Udaipur, Chittor, Bhil- wara and Jhalwar	Indore 1	1,00,000	60,000	40,000
Saurashtra	Madhya Saurashtra, Gohilwad, Zalawad, Sorath and Halar districts	Pratap	2,41,000	8,000	2,33,000
Uttar Pradesh	Meerut Muzaffarnagar, Bijnor, Saharanpur and Moradabad	35/1	1,50,000	45,345	1,04,655
Pepsu	Patiala, Sangrur, Bhatinda and Kapurthala	320F } 216F }	3,20,000	2,50,000	70,000

The actual area under cotton as well as that under improved varieties is given in Table 54. The gross extra income earned by the cultivators of the improved varieties on a modest average estimated income of Rs. 10 per acre, is also indicated. The income derived by the cultivators was actually much greater than the average income.



Fig. 46. Progress of Improved Varieties of Cotton

TABLE 54. AREA UNDER IMPROVED VARIETIES AND GROSS EXTRA INCOME

Year	Total area under cotton (thousand acres)	Area under improved varieties	Percentage of area under improved varieties to total cotton area	Extra income (crore of rupees)
<i>Pre-Partition Period</i>				
1934-35	23,972	3,761	15.7	3.8
1935-36	25,962	4,802	18.5	4.8
1936-37	24,759	4,676	18.9	4.7
1937-38	25,746	5,651	22.0	5.7
1938-39	22,490	5,663	24.1	5.7
1939-40	21,580	6,074	28.1	6.1
1940-41	23,311	5,646	28.5	6.6
1941-42	24,151	8,581	35.5	8.6
1942-43	19,203	10,382	54.1	10.4
1943-44	21,086	9,893	46.9	9.9
1944-45	14,843	8,405	56.6	8.4
1945-46	14,668	8,622	58.8	8.6
1946-47	14,860	8,240	55.5	8.2
<i>Post-Partition Period</i>				
1947-48	10,655	5,150	48.3	5.2
1948-49	11,293	5,630	49.9	5.6
1949-50	12,173	5,992	49.2	6.0
1950-51	14,556	7,244	49.8	7.2
1951-52	16,201	8,756	54.1	8.8
1952-53	15,713	9,023	57.4	9.0
1953-54	17,265	10,689	61.9	10.7
1954-55	18,684	11,837	63.4	11.8
1955-56	19,978	13,563	67.9	13.6
1956-57	19,843	14,300	72.1	14.3

Figures prior to 1947-48 relate to Undivided India and those from 1947-48 to Indian Union.

The benefits which accrued to the cultivators as a result of growing pure seed of improved varieties under the seed multiplication and distribution schemes financed by the Indian Central Cotton Committee during the year 1956-57 are shown below in Table 55 (Figs. 47 and 48).

In July, 1957, the Cotton Forecast Sub-Committee of the Indian Central Cotton Committee considered the question of co-ordinating the work done under the extension schemes and the seed multiplication and distribution schemes with a view to avoiding overlapping of work. The former were financed directly by the Government of India and the latter by the Committee and the State Governments.

TABLE 55. GROSS EXTRA INCOME EARNED BY GROWERS OF IMPROVED VARIETIES

State	Improved varieties of cotton	Total cotton area (thousand acres)	Total area covered by improved varieties (thousand acres)	Percentage of column 4 over column 3	Gross extra income earned by growers (lakh of rupees)
1	2	3	4	5	6
Andhra Pradesh	C.2, N.14, Laxmi, H.14, H.420, R.1, Westerns 1, Gaorani 6, Parbhani-American 1, and Anakapalli White	1,005	811	81	120.00
Bombay	Kalyan, Vijay, Digvijay, Vijalpa Virnar Pratap, 134-Co.2-M, 170-Co.2, Parbhani-American 1, Gaorani 6, Gaorani 12, Daulat, H.420, Buri 0394 and No. 91	10,833	5,601	51	857.00
Madhya Pradesh	Maljari, Virnar, Buri 0394, A.51-9, H.420, Bhoj, Malvi and Indore 2	2,185	711	32	71.10
Madras	M.C.U. 1, M.C.U. 2, K.2, K.5 and P.216F	1,204	546	45	259.00
Mysore	Laxmi, M.C.U. 1, 170-Co.2, Jayadhar, Virnar, M.A.5, Sel. 69, Westerns 1 and H.420	2,403	1,876	78	89.43
Punjab	320F, 216F, H.14 and Desi cottons in small pockets	1,415	1,007	71	780.00
Rajasthan	320F, Ganganagar 1, C.520, Indore 1, Virnar and 134-Co.2-M	542	229	42	25.51
Uttar Pradesh	35/1, 216F, 320F and H.14	147	93	63	7.25
Other States		109	Negligible	—	—
Total		19,843	10,878	55	2209.29

In this connection, a view was expressed that while great care was taken under the seed multiplication and distribution schemes financed by the Committee for the multiplication of pure seed of approved varieties in each tract, the standard of purity of the seed distributed under the cotton extension schemes was indefinite, which ultimately lowered the quality of the produce. It was, therefore, considered necessary to examine the working of these two schemes with a view to ensuring that pure seed of approved varieties was multiplied in States for distribution in the entire tract.

This question was discussed at length by a Special Sub-Committee in January, 1958, which recommended that the entire cotton development work

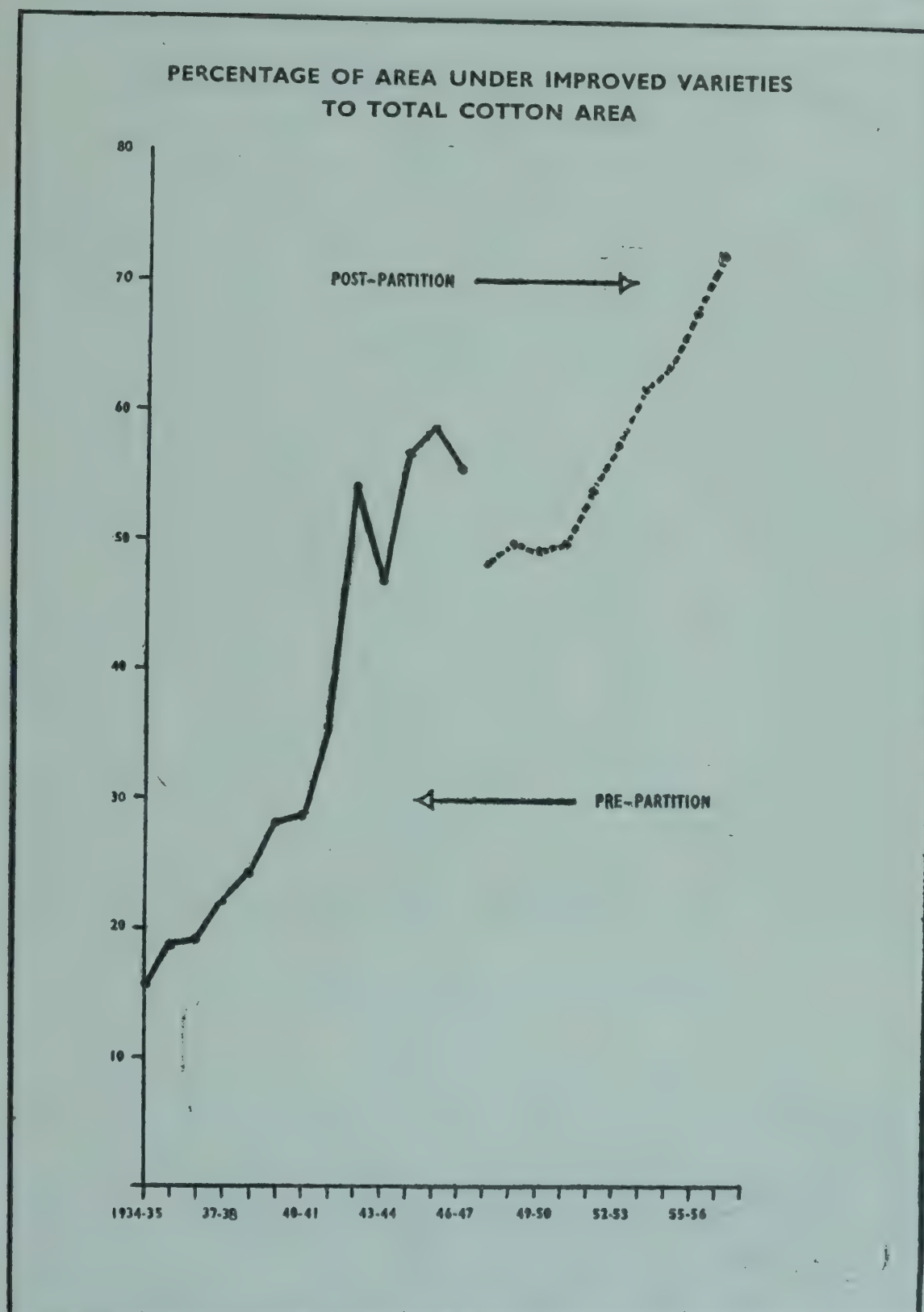


Fig. 47. Percentage of Area Under Improved Varieties

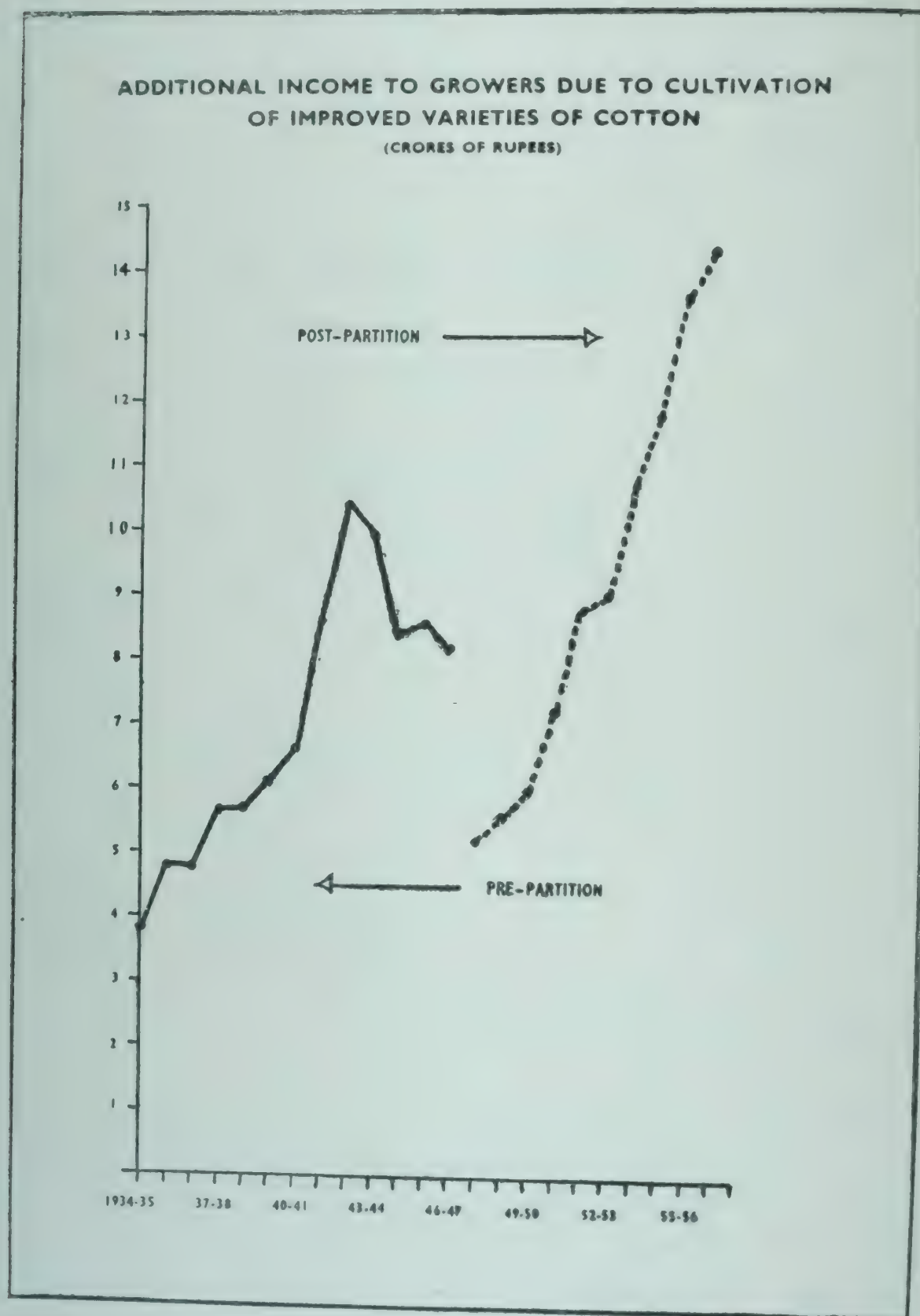


Fig. 48. Additional Income Due to Cultivation of Improved Varieties

including that of seed multiplication and distribution should be under the charge of a senior and experienced officer to be designated as Cotton Extension Officer and that an Expert Sub-Committee should be appointed to draw up a model scheme embodying the two aspects of work. It was recommended that on the amalgamation of these two schemes, a lump sum grant of Rs. 20 lakhs might be made available to the Indian Central Cotton Committee by the Government of India for meeting the requirements of individual States for purchase of improved seed, etc. Further, the proposed Cotton Extension Officer, in addition to seed multiplication and distribution work, would attend to the distribution of manures and pesticides, the introduction of improved cultural practices, etc. He would be responsible to the State Directors of Agriculture for the conduct of work under the co-ordinated scheme.

It was also recommended that the Liaison Officers proposed to be appointed to assist the State Directors of Agriculture in the enforcement of cotton legislation in the various States, might be placed under the administrative control of the Cotton Extension Officers.

It may incidentally be mentioned here that it is proposed to formulate a model seed multiplication and distribution scheme with a view to making the pure seed of improved varieties available for general cultivation within a period of four to five years by enlarging the reserved area where roguing of off-types and ginning and pressing under departmental supervision is attended to, so that the seed from that reserved area, so purified, may be immediately available for covering the entire tract with the variety recommended for extension. This, it was considered, would minimise the tendency to mix with unimproved variety and improve the purity and the quality of the crop to a great extent. Thus, it would enable the cultivators to realise better premium for their produce than at present.

WORK IN OTHER COTTON GROWING COUNTRIES

EGYPT

The Cotton Research Board is a sub-section of the Ministry of Agriculture in Egypt, and is responsible for the creation and multiplication of new varieties of cotton and the supervision of cotton seed. Under the Cotton Seed Control Law, the Egyptian Government has to arrange for meeting the entire seed requirements of the country. Practically the whole seed maintenance system is centred on the Giza Farm, controlled by the Cotton Research Board with links radiating to other Government and private farms throughout the country.

About 99 per cent. of the seed used for sowing originates from the nucleus maintained at the Central Research Board, Giza. From this nucleus, the seed is multiplied under strict Government control on the Government

Farms, State Domains and under contract on big private farms. Later, the seed is further multiplied on more private farms under contract, the Government retaining the authority of field and store inspection and for roguing the crop.

It is reported that under the provisions of Law No. 5 of 1926 (Seed Control Law), seed cotton, the seed from which is intended for sowing, must not be ginned without a licence, and ginning must be carried out under the supervision of the inspector of the Ministry of Agriculture who is attached to every licenced ginning factory. At the commencement of ginning, a certain amount of seed must be run to clear the conveyors, and not until then should the seed be collected for sowing. During the ginning process, the resulting seeds are cleaned from impurities, treated with hot air at 55° C. for five minutes to kill the larvae of the pink bollworm, and immediately packed into special sacks of definite weight.

Seed sacks of a lot are sealed for test and arranged serially in rows. Representative samples for every row are drawn according to the regulations of the International Seed Testing Association. Samples of a lot are sealed, labelled, packed together and sent to the Seed Testing Section which has three stations situated at Giza, Minia and Tanta. The following are the main features of the cotton seed tests undertaken at the above stations :

1. Preparation of the sample.
2. Test for purity of the variety.
3. Test for cleanliness.
4. Germination Test.
5. Test for larvae.

Furthermore, it would appear that an important advance was made in basing acceptance or refusal on the spinning quality of the ginned lint. Samples are now received in the form of seed cotton ; this is ginned and spinnings on the lint are carried out at the Giza Test Mill on mass production lines. If the yarn falls below the strength standard fixed for each variety, the seed is refused for sowing. Thus all the long stapled cotton of Egypt is now grown directly from seed whose lint has passed the spinning standard, lot by lot. In effect, the growers have adopted the spinners' main criterion for uniformity of deliveries, viz., yarn strength uniformity. This is a very practical step, for it is the yarn strength, more than any other factor, that determines the premium of high grade Egyptian cottons. Over and above the basis decided by economic forces, the spinner pays for his cotton chiefly according to the readings of his yarn strength tester.

It is also stated that direct control of crop quality by spinning tests and the seed examination method have obvious defects as they are effective only when considerable deterioration exists. As a reinforcement and supplement, a dated seed system is applied. All seed lots are dated by the Ministry of Agriculture according to the year when they were a nucleus. The seed

derived from these lots is refused for sowing after a certain time limit irrespective of existence of measurable deterioration or not.

An advantage of this system, to the spinners, is that cotton from the most recently renewed seed can be recognized, for the cotton as well as the seed can be labelled. Ashmouni 58, for instance, represents appreciably better staple than Ashmouni, 57, Ashmouni 56 or earlier years.

BRAZIL

The seed multiplication and distribution programme, initiated under the direction of the State Agriculture Department in 1930, is largely responsible for the high degree of uniformity of the American cottons. All growers are required by law to purchase the seed distributed by the Government. For the purchase of seed multiplication and distribution, the State is divided into different zones. A regional Agronomist, comparable to a district country agent in the United States, is appointed to supervise the multiplication, processing and distribution of planting seed. Co-operating growers are selected by the regional Agronomist and these contract to produce certified planting seed. Average farmers are usually selected, and seed multiplication fields are inspected periodically by the regional Agronomist to ensure proper isolation and adequate roguing of the seed fields to eliminate fertilisation from off-type plants.

The cotton is ginned at co-operating gins where special care is taken to keep seed stocks pure and is then sent to seed fumigation houses for carrying out germination tests, after which it is bagged and fumigated in vacuum chambers with carbon bisulphide or methyle bromide for pink boll worm eradication. It is then shipped out to seed distribution stations for sale to the cotton growers of the State. It is distributed in 66 lb. sacks and even though the price varies from year to year, it is held to the minimum and by law includes the cost of hail insurance.

ARGENTINA

The experimental stations enter into contracts on behalf of the Government with leading growers to produce first and second year seed from the superior varieties and selections from these varieties. In this way, seed from superior varieties is multiplied within a minimum period ranging from four to six years for getting newly developed varieties into commercial production. The multiplication programme is carried out under supervision of expert personnel and periodic inspections made for certifying the purity of seed stocks.

INDEX

A

- Agricultural Journal of India, 302
- Alternaria* Leaf Spot, 193-94; symptoms of, 193; etiology, 193
- Anthracnose, 181-83; symptoms of, 181; etiology, 182; control measures, 183
- Application of Plant Hormones—Effect of, 41-53; on morphological characters, 41-44; on carbohydrate and nitrogen metabolism, 44-53; phytohormones, 41
- Artificial Reproduction of *Tirak* Symptoms, 69-74
- Ascochyta* Blight, 190-91; symptoms of, 190; etiology, 191; control measures, 191
- Ascochyta gossypii*, 191
- Aspergillus niger*, 178
- Assimilatory Products, 19

B

- Bacterial Blight, 164, 195-200; symptoms of, 196-97; etiology, 197; perpetuation and dissemination of, 198; predisposing factors, 198; control measures, 199
- Bad Opening, 1, 2
- Bollworms, 217-19
- British Cotton Grower's Association, 76
- British Cotton Growing Association, 304
- Bud and Boll Shedding, 55

C

- Capnodium*, 195
- Carbohydrate and Nitrogen Metabolism, 27
- Carbohydrate/Nitrogen Ratio, 36, 37, 38
- Cercospora gossypina* Cke, 192
- Cercospora* Leaf Spot, 191-92; symptoms of, 191-92; etiology, 192; control measures, 192
- Chilean Nitrate Education Bureau, 38

Colletotrichum capsici, 182

Correlation Coefficients, 78

Cotton Aphid, *Aphis gossypii* Glover, 268, 273-74; natural enemies of, 268, 273; control measures, 273-74

Cotton Boll Weevil, *Anthonomus grandis* Boheman, 280-82; origin and spread of, 280; distribution of, 280; host plants of, 280

Cotton Bud Moth, 248-49

Cotton Jassid, *Empoasca devastans* Dist., 258-64; host plants of, 261; natural enemies of, 261; control measures, 261-64; breeding of resistant varieties, 261-63; chemical control, 263-64

Cotton Leaf Roller, *Sylepta derogata* Fb., 244-47; life-history of, 245; natural enemies of, 245-46; control measures, 246-47

Cotton Rust, 63

Cotton Semiloopers, 247-48; *Anomis flava*, 247; *Acontia graellsii*, 247; *Tarache notabilis*, 247; *T. nitidula*, 247; *T. basifera*, 247; *T. opalinoides*, 247

Cotton Stem Borer, *Sphenoptera gossypii* Cotes, 257-58

Cotton Stem Weevil, *Pempheres affinis* Fst., 250-57; host plants of, 252-54; natural enemies of, 254-57; control measures, 257

Cotton White-fly, *Bemisia tabaci*, 264-68; life-history of, 264-67; natural enemies of, 267; control measures, 267-68

Crop Rotation, 110-13, *senji* (*Melilotus parviflora*), 110; *shaftal* (*Trifolium resupinatum*), 110; *barseem* (*Trifolium alexandrinum*), 110; *methi* (*Trigonella foenumgraecum*), 110; *arhar* (*Cajanus indicus*), 112

Cultivation After Sowing, 132-34; inter-row cultivation of the standing crops, 132; weeding, 132, 133

Cumulative Effect of Sowing Date and Spacing, 9; of spacing and nitrogen, 10

D

Damping Off of Seedlings, 186-87; symptoms of, 186; etiology, 186-87

Disaccharides, 27, 29

Dusky Cotton Bug, *Oxycarenus laetus* Kirby, 275

Dysdercus nigrofasciatus, 189

E

Earias fabia Stoll, and *Earias insulana* Boisd., 228-44; life-history of 228-31; natural enemies of, 231-37; control measures, 237-40; insecticidal control, 240-41; biological control, 241-43; legislative control, 243-44

Earlier Work Under Agricultural Departments, 302-07

Edaphic and Climatic Environment, 75

Effect of Manuring on Yield, 102

Effect of Micro-Nutrients, 38-41

Effect of Nitrogen on Growth 4-5

Effect of Small Climatic Differences on Growth, 13-20; bud initiation period, 14; square period, 14; boll period, 14

Effect of Spacing on Growth, 5-8; on yield, 9

F

First Five-Year Plan, 316-20

Fruitfulness, 28

G

Grey Mildew, 189-90; symptoms of, 190; etiology, 190

H

Hairy Caterpillars, 249-50; *Euproctis fraterna*, 249; *Euproctis lunata*, 249; *Amsacta albistriga*, 249; *A. moorei*, 249; *Pericallia ricini*, 249; natural enemies of, 250; control measures, 250

Harvesting, 147-54

Heliothis armigera Hübn., 244

Helminthosporium gossypii, 193

Helminthosporium Leaf Spot, 192-93; symptoms of, 192; etiology, 193

Hypocotyledonary Region, 31

I

Implements, 113-20; *bakhar*, 114, 115, 116; *kolpa*, 114, 119; *khurpi*, 114, 119; *triphallies*, 114; *munna* (*desi* plough), 115; *guntaka*, 116; 'Victory' mould-board plough, 117; *Mogha*, *sarota* or *sadde*, 117; *dufan*, *phadak*, *tiphani*, *gorru* or *gorrukallappai*, 118, 125; *kasaula*, 119; *dauri*, 119-20; *daura* 119-20; *yade kunte* 119, 120; *danthulu*, 119; Indore Ridger, 120

Improved Varieties, 155-61; Bengals 156; Americans, 156; Oomras, 156; Gaorani, 156; Central India, 156; Surti, 156; Dholleras, 156; Southernns, 156; Tinnevellis, 156; Cambodias, 156; Madras Uganda, 157; Salems, 157; Comillas, 157

Inner Seed Farms, 310, 314

Insect and Mite Pests of Cotton in India-List of 283-86, 287-292

Internal Boll Disease, 188-89; symptoms of, 188; etiology, 189; transmission of, 189; control measures, 189; ascigerous stage, 189

International Seed Testing Association, 334

Introduction of Superior Indigenous Varieties, 304

Irrigation, Water Conservation and Drainage 143-47; dry farming, 143; surface irrigation; 144; sub irrigation and spray irrigation, 144; furrow irrigation, 144

J

Jassid-Year, 76

M

Manuring, 135-43; carting, spreading and ploughing, 136

Mealy Bug, *Ferrisiana virgata* (Ckll.) and *Pseudococcus corymbatus* Green, 275, 277

Meloidogyn incognita, 200

Meristematic Activity, 5

Mineral Composition of Cotton Plant, 20-27; mineral uptake, 25, 28; oil formation 26; reducing sugars, 27, 29

Mite Pests, 279-80; *Eriophyes gossypii* Banks, 279; *Tetranychus telarius* L., 279

Moth (*Phaseolus aconitifolius*), 180

N

Nematospora nagpuri, 189

Neocomospora vasinfecta Smith, 167

Nitrogen and Spacing, 6-8 ; limiting factor, 6 ; inter-relationship of spacing, 7

Nucleus Plot, 310, 311, 313

O

Osmotic Pressure, 79

Outer Seed Farms, 310, 314

P

Pathological Symptoms, 38

Periodic Partial Failures of American Cottons, 1

Photosynthetic Activity, 51

Phymatotrichum omnivorum, 173

Physiological Causes of Low Yields, 86-102 ; in the Punjab, 86-91 ; in Sind, 91-94 ; in Mysore, 94-102

Phytophthora parasitica, 186-87

Platyedra gossypiella Saund., 219-28 ; life-history of, 221-24 ; natural enemies of, 224-26 ; control measures, 226-28

Potash Hunger, 63

Preparation of Soil, 120-24 ; *rauni*, 121 ; tractor ploughing, 122 ; contour bunds, 124 ; terracing of fields, 124

Pressley Strength Index, 97

R

Ramularia areola, 190

Red Cotton Bug, *Dysdercus cingulatus* Fabr., 274-75

Red Leaf, 208-10 ; symptoms of, 208 ; in the Punjab, 208 ; in Central India, 209 ; in Bombay-Karnatak, 209

Red Leaf Disease, 78-86 ; in the Punjab and Sind 78-80 ; in American Uplands, 80-82 ; in Dharwar-American, 82-86

Relative Growth Rate and Net Assimilation Rate, 1-3 ; *kharif* crop, 1 ; winter crop, 1

Remedial Measures for *Tirak*, 74-77

Rhizoctonia bataticola Butler, 173, 174, 185

Rhizoctonia solani Kühn, 173, 174, 185

Root knot, 200 ; symptoms of, 200 ; etiology, 200 ; control measures, 200

Root rot, 164, 173-81 ; symptoms of, 174 ; etiology, 174-75 ; predisposing factors, 176-78 ; control measures, 178-81

Rust, 194

Ryots' Method of Cotton Cultivation, 304

S

Scale Insects, 277-78 ; *Pulvinaria maxima* Green, 277 ; *Saissetia nigra* Nietn., 277 ; *Cerococcus hibisci* Green, 277 ; Yellow scale of cotton, 277

Sclerotium Wilt, 187-88 ; symptoms of, 187 ; etiology, 187 ; control measures, 188 ; *Sclerotium rolfsii*, 187

Seed Cotton Under Field Conditions—Yield of, 53-55 ; pot culture experiments, 53

Seed Multiplication, 161-63 ; foundation stock, 162

Seed Multiplication and Distribution in States, 310-14

Seed Rate and Spacing, 127-32 ; thinning, 128, 131 ; line sown cotton, 129 ; ridge sown crop, 130

Senescence, 31, 76, 81

Setting Percentage, 56

Small Leaf, 205-06 ; symptoms of, 205 ; etiology, 205 ; control measures, 205-06

Soil Conditions to Bad Opening—Relation of, 57-61 ; *tirak*, 57, 58, 60, 61 ; light sandy soils, 58 ; tannin, 59 ; soils with saline sub-soil, 60

Soil Heterogeneity, 75

Soil Temperature Interaction in Relation to *Tirak*, 77-78

Sooty Mould, 194-95 ; symptoms of, 195 ; etiology, 195

Sore Shin or Dry Rot, 183-86 ; symptoms of, 184 ; etiology, 185 ; control measures, 185-86

Sowing—Season of, 106-10 ; method of, 124-27 ; *kharif* crop, 107 ; broadcasting, 124 ; dib-

bling of seed, 124, 126, 127 ; fuzz, 125, 126

Sukkur Barrage, 86

T

Thrips, 278-79; *Scirtothrips dorsalis* Hood, 278;
Thrips tabaci Lind., 278; natural enemies
of, 278; control measures, 278-79

Tirak-Affected Plants—Physiological Chemistry
of, 61-69

Tirak or Bad Opening, 206-08 ; symptoms
of, 206 ; etiology, 207; control measures, 207

Trichoderma lignorum, 178

V

'Vein Blight' or 'Black Vein', 196

W

Weather Blight, 190

Wilt, 164, 165-73 ; symptoms of, 166-67 ;
etiology, 167-69 ; predisposing factors,
169-70 ; perpetuation of, 170 ; spread of,
170 ; control measures, 170-71 ; microbial
antagonism, 169

Wilt-Resistant Varieties, 166, 171

Work Under Indian Central Cotton Com-
mittee, 307-10

Work Under Second Five-Year Plan, 320-33

Work in Other Countries, 333-35 ; in Egypt,
333-35 ; in Brazil, 335 ; in Argentina, 335

X

Xanthomonas malvacearum, 197, 198

Y

Years of Cotton Failures, 77

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